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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. VIII. DESCRIPTION OF SUBSYSTEM OUTPUT.

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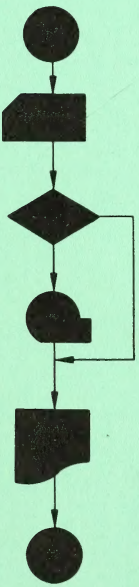

by
Robert W. Wilson Jr.
and Robert C. Peters

U. S. FOREST SERVICE RESEARCH PAPER NE-76
1967
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

About the Authors

ROBERT W. WILSON, JR. took his Bachelor's degree at The Pennsylvania State University in 1947 and his Master's and Ph.D. degrees at Yale University in 1948 and 1965, respectively. He joined the U. S. Forest Service in 1948 and has worked in various research capacities for the Northeastern Forest Experiment Station. From 1961 to 1965 he was in charge of the Station's biometrics unit at New Haven, Conn. He is assigned at present to the Forest Insect and Disease Laboratory at West Haven, Conn.

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PREFACE

THIS paper is the eighth in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

VIII-A. INTRODUCTION

ONE of the major projects of the U. S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper describes a part of the system, subsystem OUTPUT, which is a computer program designed to produce and print fully labelled tables of statistics for sampled populations from tabular summaries of the samples produced in program TABLE (see part V of this series). A complete understanding of that program is a necessary prerequisite to what follows.

The principal operations carried out by the program are the weighting and summing of selected input tables over all the sam-

ples in a population, the expansion of these sums to population totals, and the printing of the expanded tables, with labels that have been given as input. Several variations of this general procedure are provided to accommodate some of the more common sampling methods.

The program is written in the standard FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 Direct Coupled System under the IBSYS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems.

Part X in this series contains a selection of programming information that will be useful if the standard version of the program must be modified for any reason. Detailed instructions for setting up and executing jobs with the standard version are given in part IX. Copies of these publications and information on the FORTRAN IV source decks for the program can be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

VIII-B. PROGRAM OUTPUTS

The primary outputs from program OUTPUT are printed tables of statistics for sampled populations, selected from among the tabular summaries produced for the samples (data sets) in program TABLE.

The basic statistics put out for each selected table are cell-by-cell sums (including row and column totals) of the sampling-unit attributes contained in the table over all sampling units in the population, and the corresponding variances of these sums (except that the zero variances for populations wholly contained in the samples are not printed). In addition, tables of the corresponding standard errors of estimate, expressed either in absolute terms or as percentages, may be obtained on an optional basis.

Each statistic for each of the selected output tables is printed in the format specified for that table in the program TABLE job con-

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trol deck (see part VI-B sec. 320., in the description of that program). A maximum of 27 rows and 4 columns are printed per page, complete with table title, row and column headings (as supplied in the job control deck), and the name of the statistic. Larger tables are printed on multiple pages, each page being fully labelled.

Outputs equivalent to those just described can also be obtained on an optional basis for groups of populations. These statistics are simple sums of the individual population statistics.

In addition to, or in place of these primary outputs, some other modified outputs of the same general format can be obtained. For example, tables of population totals and their variances can be replaced by tables of means and their variances. Under certain conditions, the tables of population statistics can be replaced by tables of sample statistics; or, under an appropriate assumption of homogeneity within the population, by tables of statistics for particular segments of the population. However, modifications of this kind require judicious choice of a successful combination of input data, weights, expansion factors, and processing options. And they should not be undertaken without thorough understanding of the sampling method, the estimating problem, and the program logic and procedures.

VIII-C. DATA INPUTS

The data input to program OUTPUT must be a single magnetic tape file of binary records that contains the data set (sample) summaries for all populations that are to be processed in a given run. It may also contain summaries of data sets that are not to be processed in the run. These will simply be passed over during processing.

Thus, the magnetic tape file produced for these samples in program TABLE is the appropriate input to program OUTPUT, provided that care has been taken to reconcile the output option of the former with the processing option of the latter (see VIII-D). It is also necessary that the data set summaries applicable to a given population appear one after the other and in known order in the

input file. Consequently, the same order should exist in the input file to program TABLE (see V-C in the description of that program).

The formats of the input file to program OUTPUT are fully described in part VII-E of the program TABLE description.

VIII-D. PROGRAM LOGIC AND PROCEDURES

The underlying logic and procedures of program OUTPUT are quite simple (fig. 1). The first step always is to read the control deck into the computer, interpret the specifications it contains, and store the necessary information. The interpretation includes the setting up of the processing option (see below) and the output options specified in the control deck. The control deck also contains the labels to be printed with the output tables, and all weights and expansion factors required in processing the job. In the general case, this setup phase is followed by several distinct phases in which the actual processing is accomplished.

First, the entire set of tabular summary data for a sample (data set) from a given population is read into the computer; and the selected tables are weighted and summed to population totals. This phase is repeated until all samples from the population have been processed.

Second, the final population variances are computed and, if elected, so are the standard errors of estimate. After all statistics are multiplied by the appropriate expansion factors for the estimate the tables of population statistics are printed. At this point, the tables of population statistics will be summed to totals for groups of populations, if that option has been specified. This phase is repeated until all populations specified for the job have been processed and printed.

In the final phase, the tables of statistics for groups of populations, if any, are printed and the program branches back to the beginning—the reading of the control deck for the next job. This phase is repeated until all jobs in the processing run have been completed, at which point the program is halted and the run is finished.

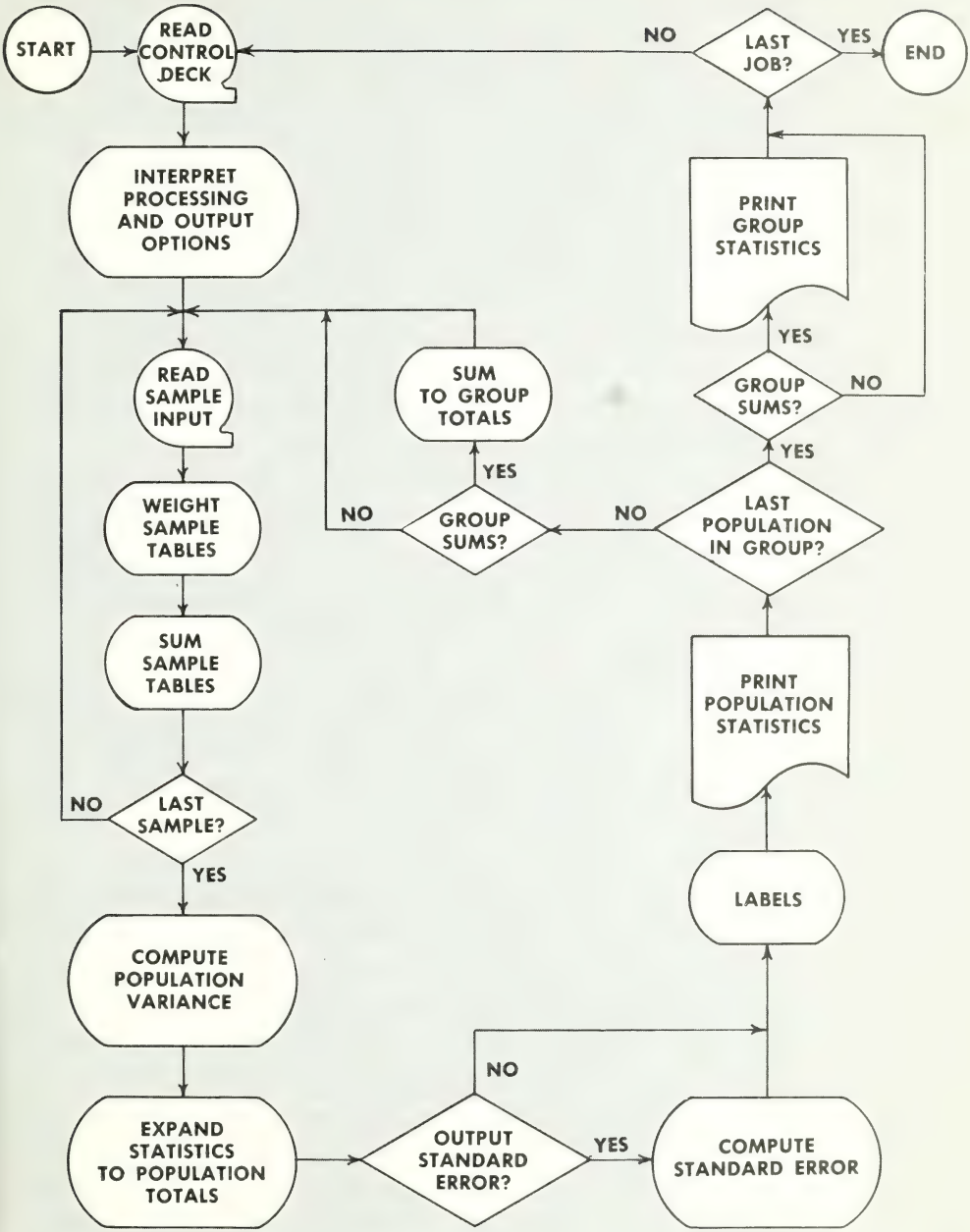

Figure 1. — A generalized flow chart of OUTPUT.

Actually, the program provides six processing options that are all special cases of the general case just described. The processing options consist of various combinations of the procedures contained in the first and second processing phases. Each option is described in detail in part X-D. In brief, they are:

1. Direct estimates of population parameters as simple sums of sample summaries; for example, when samples contain all elements of the population. These estimates require data input resulting from output option 1 of program TABLE.
2. Direct estimates of population parameters as expansions of summaries from a single sample; for example, a case of simple random sampling. These estimates require data input resulting from output option 3 of program TABLE.
3. Direct estimates of population parameters as expansions of the weighted sums of summaries from several samples, using known weights; for example, stratified random sampling from known strata. These estimates require data input resulting from output option 3 of program TABLE.
4. Direct estimates of population parameters as expansions of the weighted sums of summaries from several samples, using estimated weights; for example, stratified random sampling with double sampling for stratification. These estimates require data input resulting from output option 3 of program TABLE.
5. Ratio estimates of population parameters analogous to those of processing option 4, except that each cell of the tabular sample summaries is converted to a ratio of the tabular total and multiplied by an independent estimate of the tabular sample total before weighting and summing. These estimates require data input resulting from output option 4 of program TABLE.
6. Ratio estimates of population parameters analogous to those of processing option 4, except that each cell of the tabular weighted sums of the several samples is converted to a ratio of the tabular total and multiplied by an independent estimate of the tabular (population) total before computing the final variances and expanding the statistics. These estimates require data input resulting from output option 4 of program TABLE.

VIII-E. CONCLUSION

As described in the preceding chapters, the special purpose of program OUTPUT is to compute tables of population statistics from sample summaries, according to one of several different sampling schemes. The program is designed to be used in tandem with program TABLE so that both its inputs and outputs are controlled to a large extent by the outputs of that program; therefore, it is not well adapted for independent use in applications that do not also use program TABLE.

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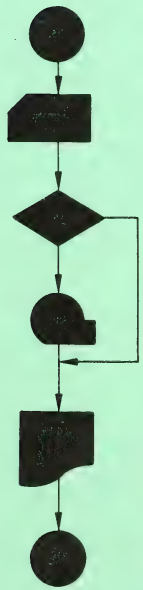

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PREFACE

THIS paper is the ninth in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

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IX-A. INTRODUCTION

ONE of the major projects of the U.S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper tells about the operation of a part of the system. Program OUTPUT is designed for use in conjunction with program TABLE (see part V of this series). Its sole function is to produce and print fully labelled tables of statistics for sampled populations from tabular summaries produced in program TABLE. Detailed instructions for solving estimation problems with the standard version of the program are given in the following chapters.

A general description of the program outputs, inputs, logic and procedures is given in part VIII of this series. The material cov-

ered there should be thoroughly digested before attempting to use the program. Presumably, the user will already be fully familiar with the use of program TABLE.

The program is written in the standard IBM FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 Direct Coupled System under the IBSYS DCS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems. Part X in the series contains a selection of programming information that will be useful if the standard version of the program must be modified for any reason.

Copies of these publications and information on the FORTRAN IV program decks may be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

In what follows, the concept of a "job" as the unit of processing is completely arbitrary. It depends on the nature of the estimating problem and the user's preferences. Any number of jobs may be included in a processing run. The only requirement is that within each job the same processing and output options, as expressed through the job control cards, sec. 410, apply to each population processed in the job; and that all populations for which the tables of output statistics are to be summed to population group totals must be contained in a single job.

Similar remarks apply to the concept of the "population" and its relation to the input data. Ordinarily, the population will be defined in its normal statistical sense, but in certain circumstances, such as estimation for parts of a "normal" population under appropriate assumptions, the population may be defined as the part for which estimates are required. Similarly, it may be defined as a group of "normal" populations. The only requirement is that the processing specifications be consistent with the definitions. It should also be noted that the same body of input data can be used repeatedly, even within the same job, in these special cases.

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IX-B. CONTROL CARD FORMATS

The description and specification of each processing job in a processing run is presented to the computer through a special deck of data cards referred to as the control deck. Each card in this deck contains specific pieces of information arranged in a definite format.

In this chapter each type of control card is described. The description gives the format of the cards, the information they must contain, and — where appropriate — the purpose and use of the required information. Consequently, this chapter may be used both as a detailed list of instructions for coding the description of a job, and as an outline to follow in the initial stages of job specification in order that the specifications be complete.

Run Title Card (Sec. 400)

This card must precede the first job control deck in the file. It simply gives a descriptive title to be printed at the top of each of the job summary pages.

Run Title Card — Item 401

Columns	*Contain* —		*Explanation*
1-72	AAA . . . A	=	72 alphameric characters, giving a descriptive title for the entire run.

Job Control Cards (Sec. 410)

The job control cards are the header cards for each job in a processing run. They contain the general specifications for the job as a whole (including table labels). Each group of job control cards in the control deck is followed by other groups of cards (described below) that give detailed descriptions of job segments.

The first card in the group, item 411, gives the number of populations to be processed in the job, the processing option to be used, and the output options. The second card, item 412, extends the output options by showing which of the sample summary tables given as input are to be processed and printed. These two cards must always be in the control deck.

The remaining cards of this group are used to provide labels

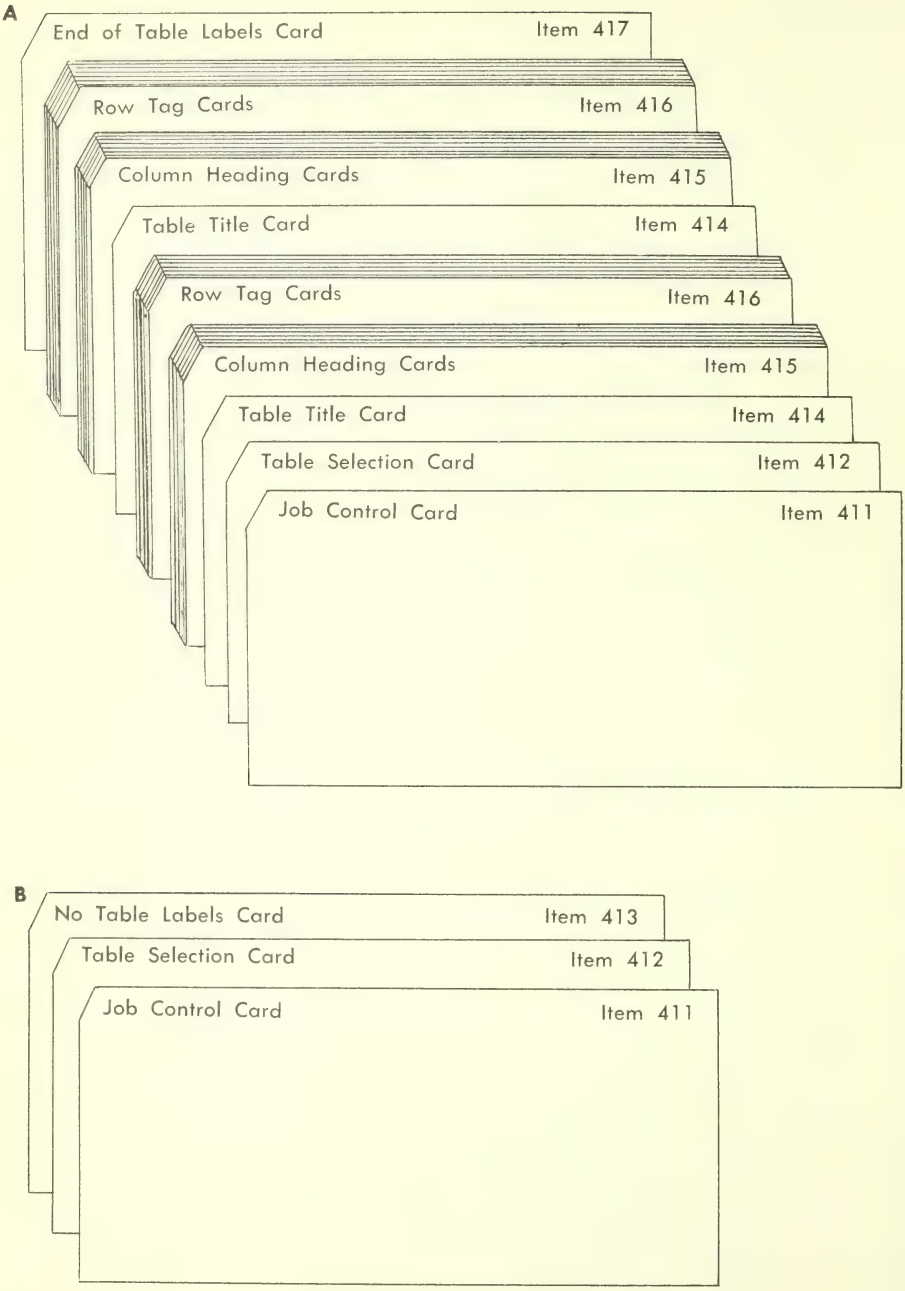


Figure 1. — Order of job control cards in control deck: **A**, the standard setup for two output tables; **B**, optional setup which may be used for any job in a run after the first.

for each table to be printed as output. These labels must always be supplied for the first job in a processing run, but they may be omitted in any subsequent job. The last set of labels read will always be used when labels are omitted for a job. This condition requires that the no table labels card (item 413) be the third and final card in the group of job control cards (fig. 1-B).

The table labels are supplied in complete sets, table by table, and in the order in which the tables occur in the input data file (fig. 1-A). A set of labels for a table consists of a table title card (item 414) that contains the table name and a descriptive title; a column heading card (item 415) for each column in the table (including the column of row totals at the extreme right of the table); and a row tag card (item 416) for each row of the table (including the row of column totals at the bottom of the table).

The entire group of table labels must always be followed by the end of table labels card (item 417).

Job Control Card — Item 411

Columns	*Contain —*		*Explanation*
1-11	JOBbCONTROL	=	Card label.
12	b		
13-15	XXX	=	3 numeric characters, giving the number of populations to be processed in this job. The number must be right-justified in the field.
16-18	000	=	Do not sum the population tables over all populations in the job.
	001	=	Sum the tables and print tables of these sums.
19-21	001	=	The data input is to be processed as a 100 percent inventory.
-	002	=	The data input is to be processed as a simple, random sample, using the direct-estimating procedure.
-	003	=	The data input is to be processed as a stratified, random sample with known weights, using the direct-estimating procedure.
-	004	=	The data input is to be processed as a stratified double-random sample with estimated stratum weights, using the direct-estimating procedure.

-	005	= The data input is to be processed as a stratified double-random sample with estimated stratum weights, using the separate weighted ratios estimating procedure.
-	006	= The data input is to be processed as a stratified double-random sample with estimated stratum weights, using the combined ratio estimating procedure.
22-24	000	= Do not produce tables of standard error estimates from the tables of variance estimates. This option must be taken if option 001 is taken in columns 19-21, because neither the variance nor the standard error estimates is appropriate to that option.
-	001	= Produce and print tables of standard error estimates, expressed as percentages of the tables of totals.
-	002	= Produce and print tables of standard error estimates, expressed in the same units as the tables of totals.

Table Selection Card — Item 412

Columns	*Contain —*	*Explanation*
1-12	TABLEbSELECT	= Card label.
13	b	
14	0	= Do not print the first table in the data input.
-	1	= Produce and print the first table in the data input. This option may be exercised sequentially for up to 67 tables in the data input, using the following columns:
15-80	X	= Repetitions of the column 14 format, giving the print option for the remaining tables in the data input.

No Table Labels Card — Item 413

Columns	*Contain —*	*Explanation*
1-9	NObLABELS	= A control word, signifying that table labels are not in the control deck for this job. This card cannot be used for the first job of a run since the labels must be present for that job. However, subsequent jobs may use the same labels, in which case this card may be used.

Table Title Card — Item 414

Columns	*Contain —*	*Explanation*
1-6	AAAAAA	= 6 alphameric characters, giving a unique name by which an input-output table may

be referenced. The name must be left-justified in the field, and must appear exactly as given in columns 14-19 of the output table definition card (item 321 in part VI).

7-78	AAA . . . A	=	72 alphameric characters, giving a descriptive title for an output table. This title will be printed on each page of output for the table.

Column Heading Card — Item 415

Columns	*Contain —*		*Explanation*
1-20	AAA . . . A	=	20 alphameric characters, giving a label for a column in an output table. The label should be centered in the field. There must be one card for each column of the table named in columns 1-6 of the appropriate table title card (item 414), and the last card of the group must be the label for the column of row totals.

Row Tag Card — Item 416

Columns	*Contain —*		*Explanation*
1-20	AAA . . . A	=	20 alphameric characters, giving a label for a row on an output table. The label should be left-justified in the field. There must be one card for each row of the table named in columns 1-6 of the appropriate table title card (item 414), and the last card of the group must be the label for the row of column totals.

End of Table Labels Card — Item 417

Columns	*Contain —*		*Explanation*
1-13	ENDbOFb LABELS	=	A control word, signifying the end of the deck of table labels. This card must always be present unless a no table labels card (item 413) has been used.

Population Description Cards (Sec. 420)

The control cards described in this section contain all of the information that is relevant in describing a population as a whole. There must be one group of these cards for each population to be processed in a job. The arrangement of the individual cards in the group for one population is shown in figure 2.

The population title card (item 421) must always be the first

card in the group. It simply contains a descriptive title for the population that will be printed at the top of every page of output for that population.

The data input identification card (item 422) must always be the next card in the group. It contains the identification of the first sample to be processed for the population, exactly as it is in the input data file (see part VI-B, sec. 330 and part VII-E). The identification is used to search the input file for the required sample summary tables. If there is more than one sample for a population, it is assumed that the input data for the additional samples follow immediately after the identified sample in the input file.

The expansion factor card (item 423) is the third card in the group, and it too must always be included. In addition to the expansion factor by which the population mean is to be multiplied, it contains the number of samples to be processed for the population, and the sum of the sample weights (see sec. 430).

Finally, if and only if processing option 6 is being used, the group of population description cards must contain a set of cards (item 424) each of which contains the independent estimates of

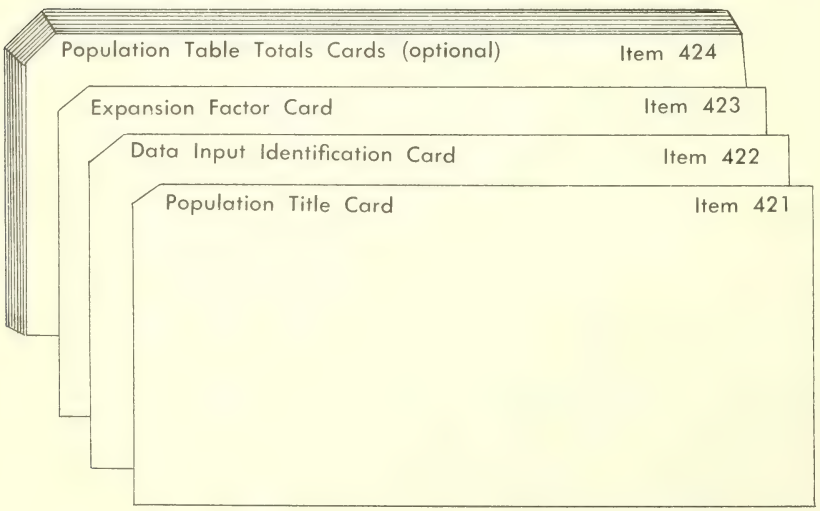


Figure 2. — Order of the population description cards in the control deck. A set of cards like this must be available for each population in a job using processing option 6. With other processing options, the last set of cards (item 424) are not used.

the population grand mean and grand variance for one of the output tables. These cards must be ordered as are the equivalent sample summary tables in the input data file.

Population Title Card — Item 421

Columns	*Contain —*	*Explanation*
1-72	AAA . . . A	= 72 alphameric characters, giving a description of a population.

Data Input Identification Card — Item 422

Columns	*Contain —*	
1-11	INPUTbIDENT	= Card label.
12-13	bb	
14-21	XXX . . . X	= 8 numeric characters, giving the first identification word in the identification record of the first sample in the block of input data for the population described in the corresponding population title card (item 421). The word must appear exactly as it does in the data input (see part VII-E). The remaining 4 identification words in the record must be reproduced in the following columns of this card. This identification record is used to search the input tape for the block of data to be processed.
22-53	XXX . . . X	= Repetitions of the columns 14-21 format, giving the remaining identification words in the first identification record in the block of input data for a population.

Expansion Factor Card — Item 423

Columns	*Contain —*	*Explanation*
1-12	EXPANb-FACTOR	= Card label.
13	b	
14-28	bX.XXXXXXXXEb-XX	= A 15-character numeric field (E specification), giving the value of the expansion factor (normally the size of the population that has been sampled) by which every cell of every output table for the population will be multiplied. This value is referred to by the symbol "wt" in the summary of estimating procedures (part X-D).
29	b	
30-32	XXX	= 3 numeric characters, giving the number of sampling strata in the population. The

			number must be right-justified in the field. If the sampling option given in columns 19-21 of the job control card (item 411) is 002, then this field must contain 001.
33	b		
34-48	bX XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the sum of the sample weights. If the sampling option given in columns 19-21 of the job control card (item 411) is 001 or 002, then this value must be 0.00000000E 00. This value is referred to by the symbol "n" in the summary of estimating procedures.

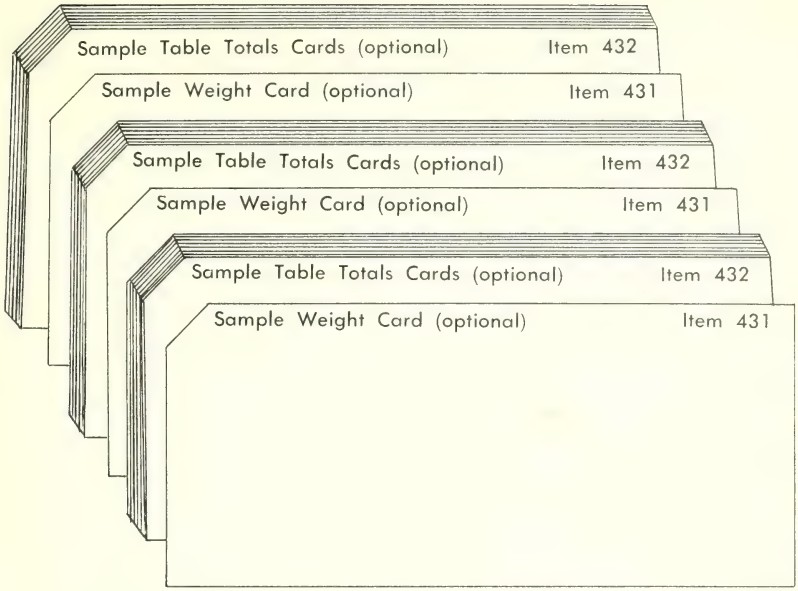
Population Table Totals Card (optional) — Item 424

Columns	*Contain —*		*Explanation*
1-12	TABLEbTOTALS	=	Card label.
13	b		
14-28	bX.XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the mean value for a population of the grand total cell of an output table. This value is referred to by the symbol "t" in the summary of estimating procedures (part X-D).
29-	b		
30-44	bX.XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the variance of the mean value in columns 14-28. This value is referred to by the symbol "vt . . ." in the summary of estimating procedures.

Sample Description Cards (Sec. 430)

The control cards described in this section appear in the control deck only if the information they contain — sample weights, and independent estimates of the sample means and variances of the grand total cell of each output table — is required by the processing option being used. If these cards are required, they must appear as a set following each set of population description cards (sec. 420). The arrangement of the individual cards in the group is shown in figure 3.

The sample weight card (item 431) is not used when processing option 1 or 2 is specified in columns 19-21 of the job control card


Sample Table Totals Cards (optional) Item 432
Sample Weight Card (optional) Item 431
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Sample Weight Card (optional) Item 431

Figure 3. — Order of the sample description cards in the control deck. The setup for a population with three samples, using processing option 5, is illustrated.

(item 411). Otherwise, there must be one card of this type for each sample in a given population. Each card contains the weight by which sample values will be multiplied before summing to population values. It also contains a second weight that may be used when estimates for a segment of the population are being made. The order of these cards in the set must be the same as that of the sample summaries in the data input file.

The sample table totals card (item 432) is used only when processing option 5 is specified in columns 19-21 of the job control card (item 411). It contains the independent estimates of sample (or stratum) mean and variance for one output table. There must be as many of these cards in the set for a sample as there are output tables, and they must be ordered in the set according to the order listed on the table selection card (item 412). The set for each sample immediately follows the corresponding sample weight card (item 431) for that sample.

Sample Weight Card (optional) — Item 431

Columns	*Contain* —		*Explanation*
1-12	STRATUMbWTS.	=	Card label.
13	b		
14-28	bX.XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the value of the weight to be applied to the data for a sampling stratum. This value is referred to by the symbol "n_j" in the summary of estimating procedures (part X-D).
29	b		
30-44	bX.XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the value of the adjustment factor to be applied to the variances for a sampling stratum when compiling estimates for a fraction of the population. This value is referred to by the symbol "n/n_j" in the summary of estimating procedures. If the value is O.OOOOOOOOEbOO, it indicates that estimates for the population as a whole are being compiled, so the adjustment factor will not be applied.

Sample Table Totals Card (optional) — Item 432

Columns	*Contain* —		*Explanation*
1-12	TABLEbTOTALS	=	Card label.
13	b		
14-28	bX.XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the mean value for a sampling stratum of the grand total cell of an output table. This value is referred to by the symbol "$\bar{t}_j$" in the summary of estimating procedures (part X-D).
29	b		
30-44	bX.XXXXXXXXEb-XX	=	A 15-character numeric field (E specification), giving the variance of the mean value in columns 14-28. This value is referred to by the symbol "$v\bar{t}_j$" in the summary of estimating procedures.

Population Group Title Card (Sec. 440)

This card is used in the control deck only if sums over all populations in the job (see item 411, columns 16-18) are required as

output. It gives a descriptive title for the group of populations represented by these sums. The title is printed at the top of every page of the "sums" output. If used, the card is placed in the control deck following all other control cards for a given job.

Population Group Title Card (optional) — Item 441

Columns	*Contain —*	*Explanation*
1-72	AAA . . . A	= 72 alphameric characters, giving a descriptive title for the tables of sums over populations in the group.

End of Run Card (Sec. 450)

This card must always be the last card in the control deck to show that there are no more jobs to be processed.

End of Run Card — Item 451

Columns	*Contain —*	*Explanation*
1-10	ENDbOFbRUN	= A control word, signifying the end of the control deck.

IX-C. OPERATING INSTRUCTIONS

The use of program OUTPUT to obtain population statistics by processing sample summary data is covered in the information given below. To facilitate checking the setup of processing runs, some of the information given is a resume of material covered elsewhere.

Program Restrictions

The standard version of the program carries limitations on the overall size and on certain dimensions of processing problems that can be handled in a single-processing run. They are:

1. The total number of summary tables for a given sample in the data input file cannot exceed 40.
2. The total number of storage locations available to produce output tables of statistics for a given population is 15,000. The limitations on the numbers of cells in all output tables for the population is more stringent and depends on the processing option being used (see part X-B).

3. The number of rows in an individual output table cannot exceed 50.
4. The number of columns in an individual output table cannot exceed 50.
5. The number of samples processed for a given population cannot exceed 999.

These restrictions result primarily from the way in which the available storage capacity of the computer has been allocated to various uses in the standard version of the program. However, the program has been constructed so that the more important of these allocations can readily be changed if a problem of substantially different relative dimensions is encountered. The modification of dimensioned space is described in part X.

Control Deck Setup

The control deck consists of all the punched cards through which processing specifications, necessary constants, and other data (exclusive of the data to be processed) are entered into the computer. These cards, and the logical groups into which they fall, have been described in the previous chapter. The assembly of the groups of control cards to form the control deck, as well as the placement of the control deck in the monitor input deck, are shown in figure 4.

It should be noted that the monitor input deck consists of the program deck, followed by the control deck, with system control cards interspersed. The latter cannot be described in detail here because they will vary from one computer installation to another. For more information about them, see the systems representative at the computer center where the processing will be done.

Input Data Setup

The normal data input is a magnetic tape file written in the binary mode and containing all the tables of sample statistics to be processed in a given run (see part VII-E of this series). The tables will be grouped in known order (see the order of the output table definition cards in the control deck for program TABLE)

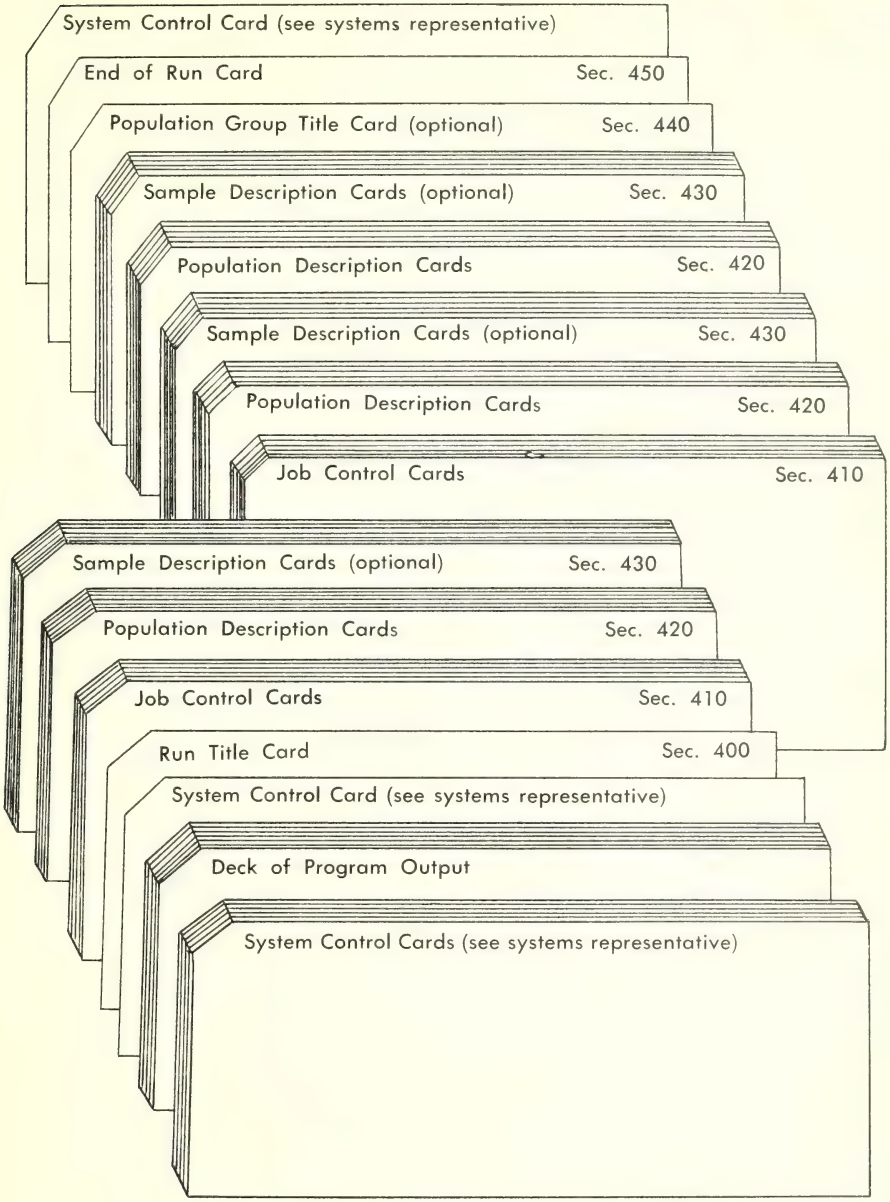
System Control Card (see systems representative)
End of Run Card Sec. 450
Population Group Title Card (optional) Sec. 440
Sample Description Cards (optional) Sec. 430
Population Description Cards Sec. 420
Sample Description Cards (optional) Sec. 430
Population Description Cards Sec. 420
Job Control Cards Sec. 410
Sample Description Cards (optional) Sec. 430
Population Description Cards Sec. 420
Job Control Cards Sec. 410
Run Title Card Sec. 400
System Control Card (see systems representative)
Deck of Program Output
System Control Cards (see systems representative)

Figure 4. — The control deck setup, illustrating the kinds of cards that are necessary and the order in which they must be arranged. The example is for a run that contains two jobs, the first requiring statistics for one population, and the second requiring statistics for two populations and the sum of the two groups.

within each sample, and the samples will be grouped in known order (see the order of the data sets in the data input file to program TABLE) within the population. Because the input data file is searched for the proper data each time a population is to be processed, the population data may be in any order and the file may also contain extraneous data which will be skipped in processing. However, all data to be processed must be contained in a single file. If it is in multiple files, then it must be processed in multiple passes.

In addition to the above requirements for the input data, they must have been produced in program TABLE under an output option that is consistent with the processing option to be used in program OUTPUT. The necessary relationships are:

OUTPUT processing option	TABLE output option	Sample summary table contain
1	1 or 2	Sample sums or means.
2	3	Sample means and their variances.
3	3	Sample means and their variances.
4	3	Sample means and their variances.
5	4	Sample means, their variances and covariances of individual means with grand means within the table.
6	4	Sample means, their variances, and covariances of individual means with grand mean within each table.

Tape Assignments

In the standard version of program OUTPUT the FORTRAN logical tape assignments are as follows:

Unit	*Use*
3	Scratch tape.
5	Monitor input for program deck and control deck.
6	Monitor print for job summary.
12	Output printed tables of population statistics.
19	Input of sample summaries written in the binary mode.

These tape assignments can be changed to fit local conditions by loading appropriate file routines with the program. See your systems representative or the section entitled FORTRAN files in the IBM IBJOB processor manual, file number 7090-27.

Use of Sense Switches and Sense Lights

No sense switches are used in the program. All sense switches will be set at normal monitor settings. No sense lights are used.

Use of Program Halts

There are no halts in program OUTPUT.

Use of Overlay Feature

The program is not constructed to use the overlay feature. All subprograms must be loaded at once.

Messages Printed During Execution

The messages listed below are those printed by the program during execution. Each message, with its consequences, is described; and the appropriate action, if any, is indicated.

Other messages may also appear in the printed summary of the run. They will be produced by the operating system under which this program is being executed. For the meaning and consequences of any message not found in the list below, see your computer systems representative.

TABLE SELECT CARD INCORRECT

Message 1. Message prints if columns 1-12 of the table selection card (item 412) are not punched TABLEbSELECT. Correct and start processing from beginning of job.

EXPANSION FACTOR CARD INCORRECT

Message 2. Message prints if columns 1-12 of the expansion factor card (item 423) are not punched EXPANbFACTOR. Correct and start processing from beginning of job.

TABLE TOTAL CARD INCORRECT

Message 3. Message prints if columns 1-12 of the survey unit table totals card (item 424) are not punched TABLEbTOTALS. Correct and start processing from beginning of job.

STRATUM WEIGHT CARD INCORRECT

Message 4. Message prints if columns 1-12 of the sampling stratum weight card is not punched STRATUMbWTS (item 431). Correct and start processing from beginning of the job.

INPUT IDENTIFICATION CARD INCORRECT

Message 5. Message prints if columns 1-11 of the data input identification card are not punched INPUTbIDENT. Correct and start processing from beginning of the job.

JOB CONTROL CARD INCORRECT

Message 6. Message prints if columns 1-11 of the job control card (item 411) are not punched JOBbCONTROL. Correct and start processing from beginning of the job.

THE TABLE NAMED AAAAAA HAS ITS TITLES OUT OF ORDER

Message 7. Message prints if the table name punched in columns 1-6 of the table title card (item 414) does not correspond with the table name on the data input tape (see part VII-E). AAAAAA is the table name which appears on item 414. Correct and start processing from the beginning.

MACHINE CAPACITY EXCEEDED — REDUCE SIZE OR NUMBER OF TABLES

Message 8. Message prints if the total number of cells necessary to produce the desired output table is greater than 15,000. Correct by reducing number of tables or altering dimension (see part X-B). Start processing from beginning of job.

■

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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. X. INFORMATION FOR PROGRAMMERS SUBSYSTEM OUTPUT.

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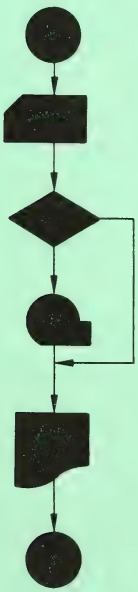

by
Robert C. Peters and
Robert W. Wilson Jr.

U. S. FOREST SERVICE RESEARCH PAPER NE-78
1967
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. X. INFORMATION FOR PROGRAMMERS SUBSYSTEM OUTPUT.

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PREFACE

THIS paper is the tenth in a series of ten papers prepared to to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

X-A. INTRODUCTION

ONE of the major projects of the U. S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper gives information for programmers about part of this system. Program OUTPUT is designed for use in conjunction with program TABLE (see part V of this series). Its sole function is to produce and print fully labelled tables of statistics for sampled populations from tabular summaries of the samples that were previously produced in program TABLE.

A general description of the program and detailed instructions for its use in solving data-processing problems are given in parts VIII and IX. In the following chapters will be found selected programming information that will be useful if the programs must be modified for any reason. The program write-ups and information on the program source decks may be obtained from

the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

The program is written in the standard IBM FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 direct coupled system under the IBSYS DCS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems. The main requirements for a machine on which to operate the standard version of the program are a 32K word core, a minimum of 36 bits per word, binary arithmetic capability, and 5 tape drives or equivalent input/output devices.

X-B. MODIFICATION OF DIMENSIONED SPACE

The standard version of program OUTPUT carries restrictions on both the dimensions and the overall size of problem that can be handled in a single processing run. These restrictions are a result of the manner in which dimensioned space has been allocated (table 1) and the total space available in a given operating system. The program has been written so that all modifications of dimensioned space can be made in the subprogram called MAINO. No other parts of the program need be touched for this purpose. The use of dimensioned space and the means of changing dimensions are discussed in detail below.

[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

Table 1. — Summary of dimensioned space restrictions, and associated program variables and arrays

Item	*Restriction*	*Variable*	*Arrays*
Maximum number of input tables	40	NTBLE	NTAB, TOTAL, TOTVAR, LTABLE
Maximum number of cells in all output tables	15,000	NDIMEN	AIMP

Number of Input Tables

In the standard version of program OUTPUT, up to 40 input tables per data set may be contained in the input data. This is consistent with the number that may be specified in the control deck for program TABLE (see item 321). To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINO, the variable named NTBLE must be set equal to the desired maximum value.
2. In the subprogram called MAINO, the DIMENSION statement must be changed so that the first dimension of the array NTAB equals the new value of NTBLE.
3. In the subprogram called MAINO, the DIMENSION statement must be changed so that the dimension of the arrays LTABLE, TOTAL, and TOTVAR equals the new value of NTBLE.

Number of Cells in All Output Tables

In the standard version of program OUTPUT, up to 15,000 locations are available for compiling output tables. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINO, the variable named NDIMEN must be set equal to the desired maximum value.
2. In the subprogram called MAINO, the DIMENSION statement must be changed so that the dimension of the array AIMP equals the new value of NDIMEN.

If the space required for compilation of the output tables specified in the output table selection card (item 412) exceeds the dimensioned space, a message will be printed during the reading of the control deck and processing will halt. The space required can be computed as follows:

$$K \left[\sum_{i=1}^{n} (r_i + 1) \times (c_i + 1) \right]$$

K = A multiplier, the value of which depends upon the sampling option (columns 19-21, item 411) and the sums option (columns 16-18, item 411) chosen; as follows:

Sampling Option	*Values of K*	
	Sums	*No sums*
1 or 2	3	2
3 or 4	6	4
5 or 6	8	6

n = The total number of output tables requested in the output table selection card (item 412).

r_i = The number of rows in the ith output table, as specified in columns 24-25 of an output table definition card (item 321 in part VI-B).

c_i = The number of columns in the ith output table, as specified in columns 27-28 of an output table definition card (item 321 in part VI-B).

X-C. PROGRAMMING FEATURES

The following items will be of interest to programmers who plan to modify the standard version of program OUTPUT for use on other computers or under other operating systems.

Tape Assignments

In the standard version of the program the FORTRAN logical tape assignments are as follows:

Unit	*Use*
3	Scratch tape.
5	Monitor input for program deck and control deck.
6	Monitor print for job summary.
12	Output printed tables of population statistics.
19	Input of sample summaries written in the binary mode.

These tape assignments can be changed to fit local conditions by loading appropriate file routines with the program. See your systems representative or the section entitled FORTRAN files in the IBM IBJOB processor manual, file number 7090-27.

Use of Sense Switches and Sense Lights

No sense switches are used in the program. All sense switches are set at normal monitor settings.

No sense lights are used.

Use of Program Halts

There are no halts in program OUTPUT.

Subprogram Names and Functions

The following tabulation lists all subprograms in program OUTPUT:

Subprogram Name	*Function*
MAINO	Main calling program.
RESULT	Major logic and calling sequence which reads and checks all control cards and sets up processing logic.
READ	Reads the binary input tape containing the sample summary tables.
ADDRES	Calculates all table addresses in array AIMP and stores them in array NTAB.
STO	Does initial weighting and summing of sample summary tables to population tables.
CALCUL	Calculates final output values for the tables of population statistics.
SETHED	Sets up the title and row and column labels for each output table, table by table.
OUTPUT	Prints the tables of population statistics with title and labels, table by table.
ERROR	Calculates sampling errors for each output table, table by table.

Important Arrays and Variables

The following are the principal arrays and variables used in program OUTPUT:

Array	*Dimension*	*Description*
AIMP	NDIMEN	Storage for all tables.
NTAB	LTBLE x 13	Indexing information for array AIMP, where LTBLE is the number of input tables for a sample and the second dimension locations are used as follows: 1 = The number of rows in the ith input table.

2 = The number of columns in the ith input table.

3 = The name of the ith input table.

4 = The beginning location in AIMP of the means for the ith input table.

5 = The beginning location in AIMP of the variances for the ith input table.

6 = The beginning location in AIMP of the covariances for the ith input table.

7 = The beginning location in AIMP of the temporary storage for the calculation of final means for the ith input table.

8 = The beginning location in AIMP of the temporary storage for the calculation of final variances for the ith input table.

9 = The beginning location in AIMP of the temporary storage for the calculation of final covariances for the ith input table.

10 = The beginning location in AIMP of the population group sums for the ith input table.

11 = The beginning location in AIMP of the population group variances for the ith input table.

12 = The location in the AIMP temporary storage for calculation of final means, of the grand mean for the ith input table.

13 = The location in the AIMP temporary storage for calculation of final variances, of the grand variance for the ith input table.

TOTAL	LTBLE	Storage for independent estimates of table grand means read from control deck, item 424 or 432.
TOTVAR	LTBLE	Storage for independent estimates of table grand variances read from control deck, item 424 or 432.
LTABLE	LTBLE	Storage for information read from the table selection card, item 412 in the control deck.
TITLE, T	12	Storage array for descriptive population title that is read in (item 421).
IDENT	6	Storage array for sample (data set) identification fields read from control deck (item 422).
IDPIO	6	Storage array for the sample (data set) identification fields read from the binary input tape.
CHEAD	51 x 4	Storage array for the column headings of an output table. Space is provided for a heading of four alphameric words (second dimension) for each of 51 columns, including row totals (first dimension).

RHEAD	51 x 4	Storage array for the row tags for an output table. Space is provided for a tag of four alphameric words (second dimension) for each of 51 rows, including column totals (first dimension).
TAB	12	Working storage.
ST	12	Working storage.
QT	12	Working storage.
VAR	2	Working storage.
RE	3	Working storage.
SST	3	Working storage.
NPSTEP	1	Total number of tables read from data input tape for a sample (data set).
PLOT IPLOT	1	Total number of sampling units used to make the data set tables read from data input tape.
AREA	1	Population expansion factor, read from control deck (item 423).
ALLPI	1	Sum of sample weights, read from control deck (item 423).
POINT	1	Sample weight, read from control deck (item 431).
ADJUST	1	Sample adjustment factor, read from control deck (item 431).
NUNIT	1	Number of samples to be processed for the population (item 423).

X-D. SUMMARY OF ESTIMATING PROCEDURES

In this chapter the six processing options available in program OUTPUT are presented in detail.

Vector notation is used to make the presentation of computing procedures more compact and easier to read. An input vector, $\overset{I}{Y}$, is a one-dimensional array representing a sampling unit attribute. An output vector, $\overset{O}{Y}$, represents an output table (in general, a two-dimensional array or matrix) summarizing the sampling unit attribute. A final output vestor, $\overset{F}{Y}$, represents an estimate of the population attribute corresponding to the sampling unit attribute. Elements of these vectors are represented by y_i, y_i, or y_i.

It must not be inferred from what follows that the arithmetic is the arithmetic of vectors or matrices; although, in general, it is correct vector arithmetic as shown. What is implied is simply

the sequential and independent application of the indicated operation to each pair of equivalent elements from the two vectors. In this sense, the procedures will generalize to the case of matrices; otherwise they will not.

Other notational conventions adopted here are the use of a bar over an attribute symbol ($\bar{Y}$) to symbolize the arithmetic mean of an attribute; and the use of a dot replacing a subscript ($y_{.jk}$) to indicate the sum over all members of the set represented by the subscript.

OPTION 1.—Process as a 100-percent Sample of the Population

Compute: $\overset{F}{Y}\ .\ .$

Given: Sets of $\overset{O}{Y}_{j.}$; and ns

Where:

- j = Subscript for the jth set of sampling units
- k = Subscript for the kth sampling unit
- $\overset{F}{Y}..$ = A final attribute vector (output table) for a survey unit, containing the sum over the entire population of sampling units of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$
- $\overset{O}{Y}_{j.}$ = An attribute vector (output table) that contains the sum over a set of sampling units of the sampling-unit attribute vectors $\overset{O}{Y}_{jk}$, which represent a summary of a sampling-unit attribute input vector
- ns = The number of sets of sampling units

Procedure: None.

Output: $$\overset{F}{Y}.. = \sum_{j=i}^{ns} \overset{O}{Y}_{j.}$$

OPTION 2.—Process as a Single Random Sample of the Population

Compute: $\overset{F}{Y}..$, $\overset{F}{VY}..$, $\overset{F}{STY}..$, and $\overset{F}{SEY}..$,

Given: $\overset{O}{Y}..$, $\overset{O}{VY}..$, and wt

Where:

- j = Subscript for the jth sample stratum or set of sampling units; hence, not applicable in this case of a single set in the survey unit

k = Subscript for the kth sampling unit

$\overset{F}{Y}\ .\ .$ = A final attribute vector (output table) for a survey unit, containing an estimate of the sum over the entire population of sampling units of the sampling-unit attribute vectors $\overset{O}{Y}_{jk}$

$\overset{F}{VY}..$ = The variance of $\overset{F}{Y}..$

$\overset{F}{STY}..$ = The standard error of $\overset{F}{Y}..$

$\overset{F}{SEY}..$ = The sampling error (in percent) of $\overset{F}{Y}..$

$\overset{O}{\overline{Y}}..$ = An attribute vector (output table) that contains the arithmetic mean of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$, which represent a summary of a sampling-unit attribute input vector

$\overset{O}{VY}..$ = The variance of $\overset{O}{\overline{Y}}..$

wt = The total number of sampling units in the survey-unit population

Output: $\overset{F}{Y}.. = \overset{O}{\overline{Y}}..\ wt$

$\overset{F}{VY}.. = \overset{O}{VY}..\ wt^2$

$\overset{F}{STY}.. = \sqrt{\overset{F}{VY}..}$

$\overset{F}{SEL}.. = \dfrac{\overset{F}{STY}..}{\overset{F}{Y}..}\ 100$

OPTION 3.—Process as Random Samples from Known Populations Strata

Compute: $\overset{F}{Y}..$, $\overset{F}{VY}..$, $\overset{F}{STY}..$, and $\overset{F}{SEY}..$

Given: Sets of $\overset{O}{\overline{Y}}_j.$, $\overset{O}{VY}_j.$, n_j ; and ns, wt

Where:

j = Subscript for the jth sample stratum or set of sampling units

k = Subscript for the kth sampling unit

$\overset{F}{Y}..$ = A final attribute vector (output table) for a survey unit, containing an estimate of the sum over the entire population of sampling units of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$

$\overset{F}{VY}..$ = The variance of $\overset{F}{Y}..$

$\overset{F}{STY}..$ = The standard error of $\overset{F}{Y}..$

$\overset{F}{SEY}..$ = The sampling error (in percent) of $\overset{F}{Y}..$

$\overset{O}{Y}_{j.}$ = An attribute vector (output table) that contains the arithmetic mean for a stratum of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$, which represent a summary of a sampling-unit attribute input vector

$\overset{O}{VY}_{j.}$ = The variance of $\overset{O}{Y}_{j.}$

n_j = The known size of stratum or weight to be applied to the stratum

ns = The number of sample strata in a survey unit

wt = Total number of sampling units in the survey-unit population

Procedure:

$$\overset{F}{Y}.. = \frac{1}{n.} \sum_{j=1}^{ns} n_j \quad \overset{O}{Y}_{j.}$$

$$\overset{F}{VY}.. = \frac{1}{n.^2} \sum_{j=1}^{ns} n_j^2 \quad \overset{O}{VY}_{j.}$$

Output:

$$\overset{F}{Y}.. = \overset{F}{Y}.. \text{ wt}$$

$$\overset{F}{VY}.. = \overset{F}{VY}.. \text{ wt}^2$$

$$\overset{F}{STY}.. = \sqrt{\overset{F}{VY}..}$$

$$\overset{F}{SEY}.. = \frac{\overset{F}{STY}..}{\overset{F}{Y}..} \quad 100$$

OPTION 4.—Process as Random Samples from Population Strata Estimated from a Primary Random Sample

Compute: $\overset{F}{Y}..$, $\overset{F}{VY}..$, $\overset{F}{STY}..$, and $\overset{F}{SEY}..$

Given: Sets of $\overset{O}{Y}_{j.}$, $\overset{O}{VY}_{j.}$, n_j, and ns, wt

Where:

j = Subscript for the jth sample stratum or set of sampling units

k = Subscript for the kth sampling unit

$\overset{F}{Y}$ = A final attribute vector (output table) for a survey unit, containing an estimate of the sum over the entire population of sampling units of the sampling attribute vectors, $\overset{O}{Y}_{jk}$

$\overset{F}{VY}\ .\ .$ = The variance of $\overset{F}{Y}..$

$\overset{F}{STY}\ .\ .$ = The standard error of $\overset{F}{Y}..$

$\overset{F}{SEY}\ .\ .$ = The sampling error (in percent) of $\overset{F}{Y}..$

$\overset{O}{\overline{Y}}_{j.}$ = An attribute vector (output table) that contains the arithmetic mean for a stratum of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$, which represent a summary of a sampling-unit attribute input vector

$\overset{O}{\overline{VY}}_{j.}$ = The variance of $\overset{O}{\overline{Y}}_{j.}$

n_j = The number of sampling units in the first (photo) sample of a sample stratum

ns = Number of sample strata in a survey unit

wt = Total number of sampling units in a survey unit population

Procedure:

$$\overset{F}{\overline{Y}}.. = \frac{1}{n.} \sum_{j=1}^{ns} n_j \overset{O}{\overline{Y}}_{j.}$$

$$\overset{F}{\overline{VY}}.. = \left[\frac{1}{n.^2 - n.} \sum_{j=1}^{ns} \left[(n_j^2 - n_j) \overset{O}{\overline{VY}}_{j.} + n_j \overset{O^2}{\overline{Y}}_{j.} \right] \right] - \left[\frac{1.0}{n. - 1} \overset{F}{\overline{Y}}^2.. \right]$$

Output:

$$\overset{F}{Y}.. = \overset{F}{\overline{Y}}.. \text{ wt}$$

$$\overset{F}{VY}.. = \overset{F}{\overline{VY}}.. \text{ wt}^2$$

$$\overset{F}{STY} = \sqrt{\overset{F}{VY}..}$$

$$\overset{F}{SEY}.. = \frac{\overset{F}{STY}..}{\overset{F}{Y}..} 100$$

OPTION 5.—OPTION 4 Modified to Obtain Stratum Ratios for Application to Independent Estimates of Stratum Means and Variances

Compute: $\overset{F}{Y}..$, $\overset{F}{VY}..$, $\overset{F}{STY}..$, and $\overset{F}{SEY}..$

Given: Sets of $\overset{O}{\bar{Y}}_{j.}$, $\overset{O}{V\bar{Y}}_{j.}$, $\overset{O}{C\bar{V}}_{j.}$, $\bar{t}_{.j.}$, $\bar{vt}_{.j.}$, n_j; and ns, wt

Where:

i = Subscript for the ith element of a vector

j = Subscript for the jth sample stratum or set of sampling units

k = Subscript for the kth sampling unit

$\overset{F}{Y}..$ = A final attribute vector (output table) for a survey unit, containing an estimate of the sum over the entire population of sampling units of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$

$\overset{F}{VY}..$ = The variance of $\overset{F}{Y}..$

$\overset{F}{STY}..$ = The standard error of $\overset{F}{Y}..$

$\overset{F}{SEY}..$ = The sampling error (in percent) of $\overset{F}{Y}..$

$\overset{O}{\bar{Y}}_{j.}$ = An attribute vector (output table) that contains the arithmetic mean for a stratum of the sampling-unit attribute vectors, $\overset{O}{Y}_{jk}$, which represent a summary of a sampling-unit attribute input vector

$\overset{O}{V\bar{Y}}_{j.}$ = The variance of $\overset{O}{\bar{Y}}_{j.}$

$\overset{O}{C\bar{V}}_{j.}$ = The mean covariance for a stratum of sampling-unit attribute vectors $\overset{O}{Y}_{jk}$, and the sums (totals) of elements in these vectors $\overset{O}{y}_{.jk}$

$\bar{t}_{.j.}$ = An independent estimate of $\overset{O}{y}_{.j.}$, the arithmetic mean over the entire population of sampling units in a sample stratum, of the sums of the elements of the sampling-unit attribute vectors $\overset{O}{Y}_{jk}$

$\bar{vt}_{.j.}$ = The variance of $t_{.j.}$

n_j = The number of sampling units in the first (photo) sample of a sample stratum

ns = Number of sample strata in a survey-unit population

wt = Total number of sampling units in a survey-unit population

Procedure:

$$R_{j\cdot} = \frac{\overset{o}{\bar{Y}}_{j\cdot}}{\overset{o}{\bar{y}}_{\cdot j\cdot}} \quad ; \quad \overset{F}{Y}_{J\cdot} = R_{j\cdot}\ t_{\cdot j\cdot}; \quad \overset{F}{\bar{Y}}\ .\ . = \frac{1}{n.} \sum_{j=1}^{ns} n_j \overset{F}{\bar{Y}}_{j\cdot}$$

$$VR_{j\cdot} = R^2_{j\cdot} \left[\frac{\overset{o}{V\bar{Y}}_{j\cdot}}{\overset{o}{\bar{Y}}_{j}{}^2_{\cdot}} + \frac{\overset{o}{v\bar{y}}_{\cdot j\cdot}}{\overset{o}{\bar{y}}{}^2_{\cdot j\cdot}} - 2\ \frac{\overset{o}{C\bar{V}}_{j\cdot}}{\overset{o}{\bar{Y}}_{j\cdot}\ \overset{o}{\bar{y}}_{\cdot j\cdot}} \right]$$

$$\overset{F}{V\bar{Y}}_{j\cdot} = \overset{F}{\bar{Y}}{}^2_{j\cdot} \left[\frac{VR_{j\cdot}}{R^2_{j\cdot}} + \frac{\bar{vt}_{\cdot j\cdot}}{\bar{t}^2_{j}} \right]$$

$$\overset{F}{V\bar{Y}}\ .\ . = \left[\frac{1}{n^2. - n.} \sum_{j=1}^{ns} \left[(n^2_j - n_j)\ \overset{F}{V\bar{Y}}_{j\cdot} + n_j\ \overset{F}{\bar{Y}}{}^2_{j\cdot} \right] \right] - \left[\frac{1.0}{n. - 1}\ \overset{F}{\bar{Y}}{}^2\ .\ . \right]$$

Output:

$$\overset{F}{Y}\ .\ . = \overset{F}{\bar{Y}}\ .\ .\ wt$$

$$\overset{F}{VY}\ .\ . = \overset{F}{V\bar{Y}}\ .\ .\ wt^2$$

$$\overset{F}{STY} = \sqrt{\overset{F}{VY}\ .\ .}$$

$$SEY\ .\ . = \frac{\overset{F}{STY}\ .\ .}{\overset{F}{\bar{Y}}}\ 100$$

OPTION 6.—OPTION 4 Modified to Obtain Population Ratios for Application to Independent Estimates of Population and Variances

Compute: $\overset{F}{\bar{Y}}\ .\ .$, $\overset{F}{VY}\ .\ .$, $\overset{F}{STY}\ .\ .$, and $\overset{F}{SE\bar{Y}}\ .\ .$

Given: Sets of $\overset{o}{\bar{Y}}_{j\cdot}$, $\overset{o}{V\bar{Y}}_{j\cdot}$, $\overset{o}{C\bar{V}}_{j\cdot}$, n_j; and $\bar{t}\ .\ .$, $\bar{vt}\ .\ .$, ns, wt

Where:

i = Subscript for the ith element of a vector

j = Subscript for the jth sample stratum or set of sampling units

k = Subscript for the kth sampling unit

$\overset{F}{\bar{Y}}\ .\ .$ = A final attribute vector (output table) for a survey unit, containing an estimate of the sum over the entire popula-

tion of sampling units of the sampling-unit attribute vectors, $\overset{o}{Y}_{jk}$

$\overset{F}{VY}..$ = The variance of $\overset{F}{Y}..$

$\overset{F}{STY}..$ = The standard error of $\overset{F}{Y}..$

$\overset{F}{SEY}..$ = The sampling error (in percent) of $\overset{F}{Y}..$

$\overset{o}{\bar{Y}}_{j.}$ = An attribute vector (output table) that contains the arithmetic mean for a stratum of the sampling-unit attribute vectors, $\overset{o}{Y}_{jk}$, which represent a summary of a sampling-unit attribute input vector

$\overset{o}{VY}_{j.}$ = The variance of $\overset{o}{\bar{Y}}_{j.}$

$\overset{o}{CV}_{j.}$ = The mean covariance for a stratum of sampling-unit attribute vectors, $\overset{o}{Y}_{jk}$, and the sums (totals) of elements in these vectors $\overset{o}{y}_{.jk}$

n_j = The number of sampling units in the first (photo) sample of a sample stratum

$\bar{t}...$ = An independent estimate of $\overset{F}{y}...$, the arithmetic mean over the entire population of sampling units, of the sums of the elements of the sampling-unit attribute vectors, $\overset{o}{Y}_{jk}$

$\bar{vt}...$ = The variance of $t...$

ns = Number of sample strata in a survey unit.

wt = Total number of sampling units in the survey-unit population

Procedure:

$$\overset{F}{\bar{Y}}.. = \frac{1}{n.} \sum_{j=1}^{ns} n_j \overset{o}{\bar{Y}}_{j.}; \qquad R. = \frac{\overset{F}{\bar{Y}}..}{\overset{F}{\bar{y}}...}$$

$$\overset{F}{\bar{VY}}.. = \left[\frac{1}{n.^2 - n.} \sum_{j=1}^{ns} [(n^2_j - n_j)\ \overset{o}{\bar{VY}}_j + n_j\ \overset{o}{\bar{Y}}^2_{j.}] \right] - \left[\frac{1.0}{n. - 1}\ \overset{F}{\bar{Y}}^2.. \right]$$

$$\overset{F}{CV}.. = \left[\frac{1}{n.^2 - n.} \sum_{j=1}^{ns} \left[(n^2_j - n_j) \overset{o}{CV}_{j.} + n_j \overset{o}{\bar{Y}}_{j.} \overset{o}{\bar{y}}_{.j.} \right] \right] -$$

$$\left[\frac{1.0}{n. - 1} \overset{F}{\bar{Y}}.. \overset{F}{\bar{y}}... \right]$$

$$VR. = R^2. \left[\frac{\overset{F}{V\bar{Y}}..}{\overset{F}{\bar{Y}^2}..} + \frac{\overset{F}{v\bar{y}}...}{\overset{F}{\bar{y}^2}...} - 2 \frac{\overset{F}{C\bar{V}}..}{\overset{F}{\bar{Y}}.. \overset{F}{\bar{y}}...} \right]$$

$$\overset{F}{\bar{Y}}.. = R. \bar{t}...$$

$$\overset{F}{V\bar{Y}}.. = \overset{F}{\bar{Y}^2}.. \left[\frac{VR.}{R^2.} + \frac{v\bar{t}...}{\bar{t}^2...} \right]$$

Output:

$$\overset{F}{\bar{Y}}.. = \overset{F}{\bar{Y}}.. wt$$

$$\overset{F}{VY}.. = \overset{F}{V\bar{Y}}.. wt^2$$

$$\overset{F}{STY} = \sqrt{\overset{F}{VY}..}$$

$$\overset{F}{SEY}.. = \frac{\overset{F}{STY}..}{\overset{F}{\bar{Y}}..} 100$$

■

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Seedbed-preparation methods for PAPER BIRCH

by John C. Bjorkbom

U.S. FOREST SERVICE RESEARCH PAPER NE-79
1967

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JOHN C. BJORKBOM received his Bachelor of Science degree in forestry at Pennsylvania State College in 1938, and worked 3 years for the Pennsylvania Department of Forest and Waters (interrupted by military service). He joined the Northeastern Forest Experiment Station in 1948, working in forest survey in the Northeast and in research with northern hardwoods in New Hampshire. In 1959 he was assigned to the Northeastern Station's unit at Orono, Maine, where he is studying the problems of regeneration and management of paper birch.

THE SEEDBED REQUIREMENT

PAPER BIRCH is known to regenerate best on disturbed seedbeds where the mineral soil is exposed or is mixed with humus. The advantages of such a seedbed are common knowledge: the roots of the new germinates can penetrate into the mineral soil more easily and quickly than into other seedbeds; mineral soil does not dry out as quickly as humus or litter layers; and surface temperatures are lower on mineral soil (*2, 4*).

This preference for mineral soil seedbeds helps to explain the scarcity of extensive stands of pure paper birch. The wildfires of the past that probably created the kind of seedbeds necessary for paper birch regeneration have become rarities because of modern fire-prevention and control techniques. And modern logging operations seldom provide the required seedbed conditions over extensive areas.

How, then, can favorable seedbeds be provided? And must specially prepared seedbeds be provided to regenerate paper birch? These questions are faced by every forester whose management objectives include the regeneration of this species. To find some answers, the Northeastern Forest Experiment Station began a study in 1958 to learn more about the effect of seedbed preparation on paper birch regeneration. This report presents the results of that study.

THE STUDY AREA

The study area, situated on a low-lying ridge about 200 feet in elevation, is located on the Penobscot Experimental Forest in Maine. The land has a gentle northeasterly aspect. The soil underlying most of the area is the Thorndike stony silt loam, well-drained and shallow to fractured shale bedrock. Some small depressions within the study area collect water and, in some years, remain wet into the summer months.

The forest stand occupying this area originated after a fire about 70 years before the establishment of the study (fig. 1). The species present in order of abundance were as follows:

Red Maple	*Acer rubrum* L.
Paper birch	*Betula papyrifera* Marsh.
American beech	*Fagus grandifolia* Ehrh.
Balsam fir	*Abies balsamea* (L.) Mill.
Red spruce	*Picea rubens* Sarg.
Gray birch	*Betula populifolia* Marsh.
Bigtooth aspen	*Populus grandidentata* Michx.
Sugar maple	*Acer saccharum* Marsh.

In general, the trees were small. None of them exceeded 13 inches d.b.h. and about three-fourths of them were in the 2-to-4-inch class. The stand volume averaged about 8 cords per acre, of which 75 percent was paper birch. The remaining volume was mostly in red maple and aspen, with minor amounts in the other species.

Within this stand, a study area 7 chains square was laid out to include 8 plots surrounded by a ½-chain isolation strip. Each plot was 1.5 by 3.0 chains, or 0.45 acre. The entire study area was then clearcut except for 50 paper birch seed trees evenly distributed over the plots at a density of about 14 trees per acre. The seed trees averaged 7.8 inches d.b.h. and 55.2 feet tall.

The eight plots were treated with four seedbed-preparation methods. Each treatment was applied to two plots. These treatments were: (1) disking after winter logging, (2) burning after winter logging, (3) summer logging with no supplemental treat-

ment, and (4)winter logging with no supplemental treatment (control).

Each plot was sampled by means of 100 randomly located milacre subplots to determine the tree species present, the percent of mineral soil exposed, the percent of stocking, and the degree of deer browsing. In 20 of the subplots on each main plot, one 1/4-milacre was used for estimating the numbers of germinates per acre and the distribution of seedlings by height classes. Two seed traps, each 3 feet square, were placed on each plot to estimate seedfall.

Figure 1.—The forest stand before cutting.

SEEDBED PREPARATION

In March 1958, with snow still on the ground, the isolation strip and all plots except those scheduled for summer logging were cut. The summer-logged plots were cut in June 1958. All the merchantable pulpwood was stump-cut and tractor-yarded with a rubber-tired flat trailer. On all plots, the unmerchantable trees, saplings, and advance reproduction more than 3 feet in height were cut after logging and left as slash. In effect, the only trees left standing were the seed trees and seedlings less than 3 feet tall (fig. 2).

Figure 2.—After clearcutting, the seed treees were essentially the only trees left standing, and slash covered the area.

The disking was done in August 1958 by using an Athens disk harrow weighted with 300 pounds of sand. To facilitate this operation, the stumps were cut to ground level, and the slash was bulldozed off the plots. Even so, repeated passes with the harrow were required for complete scarification of the soil.

The burning treatment also was carried out in August. To confine the fire within prescribed limits, the slash was pulled back from the plot boundaries. A good burn was achieved; most of the smaller slash was completely consumed.

RESULTS

The results in terms of exposed mineral soil, species present, stocking, and height growth are based on data from 800 milacre and 160 1/4-milacre sampling units. These units were first measured in September 1958 and then annually till the final measurement in September 1963.

The data on seedlings of paper birch and the other common pioneer species on the plots—gray birch, pin cherry (*Prunus pensylvanica* L. f.), and bigtooth aspen—are reported separately. Seedlings of all other hardwood species are combined as "other hardwoods"; similarly, all softwoods and all hardwood sprouts are each lumped together.

Data on the seed crops for 1958-60 are based on monthly catches of paper birch seed from August until spring each year.

Exposed Mineral Soil

Disking and burning exposed the greatest amount of mineral soil—74 and 70 percent respectively—and the distribution of mineral soil was relatively even over the plots. All of the 400 sample milacres in these treatments had at least 10 percent of their

area in exposed mineral soil; 85 to 90 percent of them had mineral soil exposed on one-half or more of their area.

On the other hand, summer-logging and winter-logging exposed mineral soil on only 6 percent and 5 percent of the respective plot areas. About three-fourths of the milacres in these treatments were not scarified at all or had only a trace of their area exposed; 99 percent of them had less than one-half of their area in mineral soil.

In general, our results are in keeping with results obtained in New Hampshire *(3)* and in the Lake States *(1)*.

Seed Supply

The amount of paper birch seed dispersed over the study area—and its viability—differed considerably among the 3 years of record. The 1958 seedfall was an estimated 1,300,000 seeds per acre, and the average germination was 13 percent. This seed crop produced most of the paper birch regeneration on the plots.

The seedfall in 1959 was about 800,000 seeds per acre and the average germination was 24 percent. In 1960 the figures soared to 16,800,000 seeds per acre and 77 percent average germination. Each of these seed crops, by seeding in the blanks from the preceding years, contributed to the total regeneration.

The seedfall varied among plots and treatments without any discernible pattern except that seedfall was rather consistently less on the two burned plots: the mean was never more than about one-half the means for the other treatments. However, enough seed from the 1958 crop fell on all plots to produce ample regeneration the next year.

Presence of Species

Seedbed-preparation method had a strong influence on the abundance of the species that were present, but had little if any influence on species' presence or absence. As shown in table 1, most species or species groups were represented in all treatments in 1959 and thereafter, but numbers per acre differed considerably.

Differences in abundance of paper birch between the disked plots and the logged-only plots are believed to be mainly a reflec-

Table 1. — *Number of stems per acre, by species, origin, and treatment, September 1958, 1959, and 1963*

(In thousands of stems)

Origin and species	1958				1959				1963			
	Disked	Burned	Summer logged	Winter logged	Disked	Burned	Summer logged	Winter logged	Disked	Burned	Summer logged	Winter logged
Seedlings:												
Paper birch	1	2	1	5	245	50	66	34	50	19	12	8
Gray birch	0	0	0	0	7	2	2	1	5	3	3	1
Pin cherry	0	0	0	0	10	6	7	6	2	2	2	1
Aspen	0	0	0	(1)	19	2	2	(1)	9	2	2	(1)
Other hardwoods	(1)	0	1	5	1	1	1	2	(1)	0	1	1
Softwoods	(1)	0	5	3	1	(1)	5	2	1	0	5	2
Hardwood sprouts	10	7	8	22	2	2	7	6	(1)	(1)	2	4
Total	11	9	15	35	285	63	90	51	67	26	27	17

[1] Fewer than 500 stems per acre.

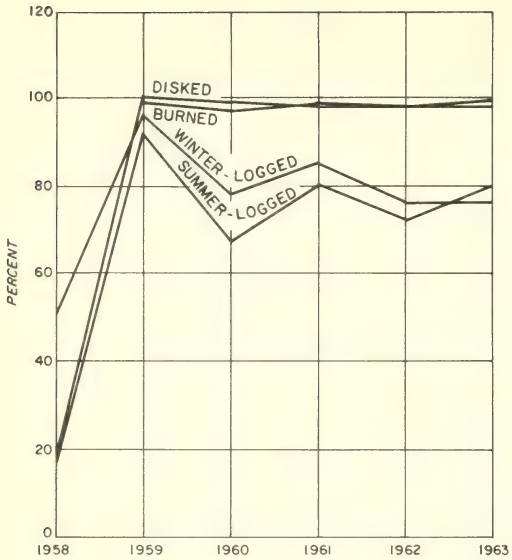

Figure 3.—The percent of milacres containing paper birch seedlings, by treatment and year.

tion of the amount of exposed mineral soil. But mineral soil seedbeds are not enough to guarantee paper birch regeneration. The burned plots, with a high proportion of area in exposed mineral soil, did not do nearly so well.

The reasons for this are not clear. Although the lighter seedfall on the burned plots doubtless was a limiting influence, some other unfavorable factor apparently was involved. Perhaps the smoother, more compact seedbed surfaces were less conducive to seed lodgment, germination, and early seedling survival than the disked surfaces.

The abundance of the other hardwoods and the softwoods was also influenced by treatment. Since these species were generally present as advance growth, their numbers were reduced particularly by the disking and burning treatments.

The method of seedbed preparation apparently had little effect on species' presence, and it is particularly significant that the kind of treatment did not appreciably affect the presence of paper birch. In September 1959, nearly every milacre in every plot had some paper birch present. Although the number of these milacres with birch decreased with time in the summer-logged and winter-

logged plots, a minimum of 76 percent of these milacres still bore paper birch seedlings in 1963 (fig. 3).

In addition to tree species, some grasses and shrubs were also present. Together they have had a limiting influence on forest tree regeneration.

Although grasses were found on all plots to some degree, they were far more common on the disked and burned plots. The wet areas appeared to be particularly susceptible to invasion by grasses. Where there is a heavy cover of grass, some paper birch seeds may not even reach the ground, and any germinates that do begin may be smothered. Sweet fern *(Myrica asplenifolia* L.), found principally on the disked and burned areas, produced patches of dense cover that also limited paper birch regeneration.

Stocking

Stocking was estimated on the basis of milacre sampling units. A milacre was considered stocked if it contained a seedling or sprout of a commercial forest tree species. Where more than one stem was present, the tallest seedling or sprout was recorded as the stocking species. Stocked milacres, expressed as percent of the total number of milacres observed, were used to evaluate the effectiveness of the seedbed-preparation methods.

At the end of the 1958 growing season—the first fall after the treatments were completed—the winter-logged control plots were fully stocked and the summer-logged plots were 91-percent stocked. Because only about 2 months had elapsed since the disking and burning were done, the treated plots were less than two-thirds stocked.

Hardwood sprouts stocked many more milacres in the fall of 1958 than did seedlings and were most abundant on the winter-logged areas. In general, red maple and paper birch sprouts were most common. At the same time, seedling stocking on both the winter-logged control plots and the summer-logged plots was mainly softwood species—spruce, fir, hemlock, and white pine. Much of this was advance reproduction. On the disked and burned plots, most of the seedling stocking was hardwoods—roughly one-half pioneer species and one-half other hardwoods. Here ad-

Table 2.— *Percent of milacres stocked, by species, origin, and treatment, September 1958, 1959, and 1963*

Origin and species	1958				1959				1963			
	Disked	Burned	Summer logged	Winter logged	Disked	Burned	Summer logged	Winter logged	Disked	Burned	Winter logged	Summer logged
Seedlings:												
Paper birch	7	5	0	2	36	17	7	20	36	34	12	15
Gray birch	0	1	0	0	7	10	0	3	5	4	4	2
Pin cherry	0	0	0	0	36	41	17	10	1	6	2	2
Aspen	0	0	0	0	4	20	2	1	47	46	11	11
Other hardwoods	7	4	9	2	1	0	3	12	1	0	3	5
Softwoods	9	2	41	22	2	0	35	19	2	1	40	29
Hardwood sprouts	40	52	41	74	14	12	36	35	7	8	27	36
Not stocked	37	36	9	0	0	0	0	0	1	1	1	0
Total	100	100	100	100	100	100	100	100	100	100	100	100

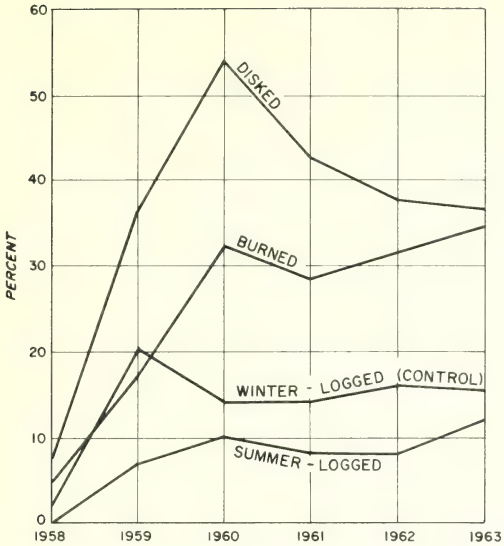

Figure 4.—The percent of milacres stocked with paper birch seedlings, by treatment and year.

vance growth was less common because much of what had been present had been destroyed by these seedbed treatments.

In April 1959 the hardwood sprouts, except paper birch and gray birch, were cut back and the stubs were treated with 2,4,5-T, thus the sprout stocking was reduced considerably. With each year after 1959, the sprout stocking continued slowly to decrease.

By the fall of 1963, paper birch seedlings stocked two to three times as many milacres on the disked plots and burned plots as on the summer-logged plots and winter-logged control plots. These differences, however, were not statistically significant at the 5-percent level. Aspen had responded similarly to the treatments, and stocked more milacres on the disked and burned plots than on the other plots; but here the differences were significant. Hardwood sprouts, on the other hand, stocked significantly fewer milacres in 1963 on the disked and burned plots than on the other plots.

The percent of stocking by species and treatments for 1958, 1959, and 1963 is shown in table 2, and the stocking to paper birch seedlings is shown graphically in figure 4.

Height

Among the seedlings tallied as stocking stems, those of aspen generally made the best height growth in all treatments. Their average heights ranged from 3.0 to 5.8 feet in September 1963. The closest seedling competitors were the advance hardwood and softwood reproduction. On the basis of stocking stems, paper birch, gray birch, and pin cherry were the smallest species, and there was little difference among them (table 3). Differences among the 1963 mean heights of stocking stems shown by species and treatments in table 3 were not statistically significant.

When all seedling stems were considered, paper birch seedlings tended to run smaller than those of all the other species, as shown by the distribution of size classes in table 4.

Total height appears to have been adversely affected by a number of factors. The more obvious ones were browsing by deer and, for the birches, attacks by the birch leaf miner *(Fenusa pusilla)* (Lep) *(=pumila* Klug).

Deer browsing was common and ever-present throughout the study area. None of the hardwood species escaped damage, and certainly paper birch bore its share. Attacks by the birch leaf miner were an annual occurrence. The infestations appeared to be more

Table 3. — *Average height of stocking stems by species and treatments, September 1963*

Origin and species	Average height			
	Disked	Burned	Summer logged	Winter logged
	Feet	*Feet*	*Feet*	*Feet*
Seedlings:				
Paper birch	2.5	2.8	2.6	2.9
Gray birch	2.6	2.6	2.2	3.2
Pin cherry	2.5	3.2	2.7	2.6
Aspen	3.0	3.6	5.8	4.8
Other hardwoods	3.7	—	3.3	6.0
Softwoods	3.5	3.2	4.4	4.0
Hardwood sprouts	4.5	4.9	6.6	6.8

Table 4. — *Distribution of species by height classes, September 1963*

Origin and species	Height class		
	Under 1 foot	1 to 3 feet	Over 3 feet
	Percent	*Percent*	*Percent*
Seedlings:			
Paper birch	33	67	0
Gray birch	37	57	6
Pin cherry	19	81	0
Aspen	13	77	10
Other hardwoods	29	47	24
Softwoods	28	61	11
Hardwood sprouts	2	39	59

severe on gray birch, but most of the paper birch was also infested. Mice and hares also caused some damage, but their combined effect on either seedling or sprout height was relatively unimportant.

DISCUSSION

The results of this study suggest that abundant paper birch regeneration can be obtained if mineral soil is exposed on a large part of the regeneration area. However, the physical difficulties and the expense of disking and burning to expose mineral soil are such that alternative methods for obtaining the desired stocking of paper birch should be considered.

Both winter-logging and summer-logging without further treatment to expose mineral soil seem to provide conditions for obtaining adequate regeneration, provided it can be maintained in the new stand. In this study, paper birch seedlings were found on

about three-fourths of the sample milacres on these treatments. The numbers of seedlings ranged from 8 to 12 thousand per acre —a sizeable resource that should not be overlooked.

But how these young stands will develop can only be guessed at. Is this seedling density at the end of six growing seasons sufficient to produce a commercial timber crop in the future? Are cultural treatments needed to bring enough seedlings through to maturity? What will be the effect on future tree quality? Clearly, investigation of stocking density and early silvicultural treatments might well be worthwhile, not only to help evaluate the need for seedbed preparation, but also to provide management guidelines for the development of more productive paper birch stands.

From our present knowledge, it seems safe to say that if a forest manager has as his objective the development of pure or nearly pure stands of paper birch, his chances of success would be enhanced considerably by making a special effort to expose the mineral soil. On the other hand, if his objective is to regenerate a new stand containing a fair proportion of paper birch in mixture with trees from the advance growth of other species, then clear-cutting alone might be satisfactory. In either case, an adequate supply of viable seed must be at hand, either from reserved seed trees, as in this study, or from bordering stands for strip and patch cuttings.

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SAWMILL

PRACTICES AND PROBLEMS

IN THE APPALACHIAN HILL COUNTRY OF OHIO AND KENTUCKY

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by Orris D. McCauley and James C. Whittaker

U. S. FOREST SERVICE RESEARCH PAPER NE-80
1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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THE IMPORTANCE OF SAWMILLS

SAWMILLING is especially important to the economy of the hill country of Ohio and Kentucky. Here—in a region of unemployment, underemployment, and low per-capita income—sawmilling is one of the few existing industries. The extensive forest resource favors this industry. Yet in the past decade the number of sawmills operating in this region has steadily decreased.

Concerned over this situation, the U. S. Forest Service has undertaken studies to determine what might be done to stabilize the sawmill industry by increasing its efficiency in producing and marketing its products. This is a report on a study to learn more about this industry—the operational characteristics and types of sawmills—and to identify the problems in lumber production.

STUDY PROCEDURE

Before the mills to be studied were selected, the area was divided into five sub-areas (fig. 1). Within each sub-area, mills were selected at random to assure equal representation of comparable operating mills. In all, 40 mills were selected for study.

The mills selected for study were mills that normally sell 500,000 or more board feet of lumber products annually. The 40 mills included some mills that normally sell this quantity of lumber annually, but whose sales in 1960 fell below this average annual.

Mills of this size were chosen because they generally are permanently located, operate year around, and maintain operating records. The mills in this size class account for as much as 75 percent of the lumber marketed in the region.

Figure 1.—The hill country of Ohio and Kentucky, showing sub-areas in which sawmills were selected for study.

SAWMILL CLASSES

Three types of mills were found in our study: (1) *grade-lumber mills*—those primarily engaged in producing lumber for sale under National Lumber Association rules;[1] (2) *pallet mills*—those engaged mainly in producing pallet lumber, blocking, and crating; and (3) *local-use mills*—those manufacturing lumber principally for local contractors, farmers, coal mines, and other local users. On this basis, 23 of the sample mills were classed as grade-lumber mills, 9 as pallet mills, and 8 as local-use mills.

Mills of the three types were found to occur in geographic clusters. Most of the pallet mills were located in southern Ohio and northern Kentucky, whereas a large proportion of the grade-

[1]National Hardwood Lumber Association. RULES FOR MEASUREMENT AND INSPECTION OF HARDWOOD LUMBER, CYPRESS, VENEERS, AND THIN LUMBER. NHLA, Chicago, Ill., January 1963-64.

lumber mills and most of the local-use mills are in the southern portion of the study area.

The most likely reasons for the concentration of pallet mills in the northern areas are: (1) the area has a cheap and readily available source of sawlogs; (2) the pallet manufacture in this area is primarily by hand labor and the area has an available supply of unskilled and semi-skilled laborers; and (3) the area is within economic hauling distance of pallet markets.

In the southern portion of the study area, higher quality, less accessible, more heavily forested tracts and the proximity of grade-lumber markets in the furniture industry best explains the development of grade-lumber mills. Here markets for fence boards, barn lumber, mine timbers, and similar products have encouraged the development of local-use mills.

Table 1.—Kind of equipment used at study mills, by mill types
(In percent of mills)

Kind of equipment	Grade lumber	Pallet	Local use	All mills
Power unit:				
Size:				
Under 75 hp.	0	33	13	10
75 to 100 hp.	22	67	37	35
Over 100 hp.	78	0	50	55
Kind:				
Electric	30	56	12	33
Diesel	61	33	76	57
Gasoline	9	11	12	10
Headsaw size:				
Under 56 inches	0	44	37	17
56 to 60 inches	43	23	26	35
Over 60 inches	57	33	37	48
Edger:				
2-saw	30	67	50	42
3-saw	65	22	37	50
More than 3-saw	5	6	0	2
Swing cut-off saw	78	67	62	72
Forklift	35	89	12	42
Double-end trimmer	43	0	25	30
Log turner	35	0	12	22

OPERATIONAL CHARACTERISTICS

Mill Equipment and Facilities

Grade-lumber mills were found to be better equipped than local-use mills, and local-use mills were generally better equipped than pallet mills. This was true for most equipment items—power units over 100 horsepower, headsaws over 60 inches in diameter, 3-saw edgers, double-end trimmers, and log turners (table 1).

The only significant deviation from this pattern was in the use of forklift trucks. Almost nine-tenths of the pallet mills had forklift trucks, compared to about one-third of the grade-lumber mills and one-tenth of the local-use mills. Pallet mills have more need for forklift trucks because they have greater problems in handling materials.

Most study mills were housed in semipermanent shelters with maintenance shops attached. Most had log and lumber yards of 1 acre or larger; most had small office buildings.

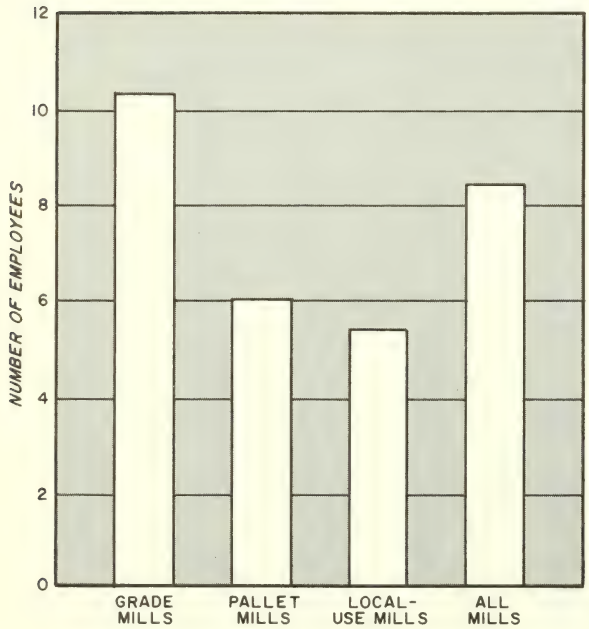

Figure 2.—Average number of production employees, by mill type.

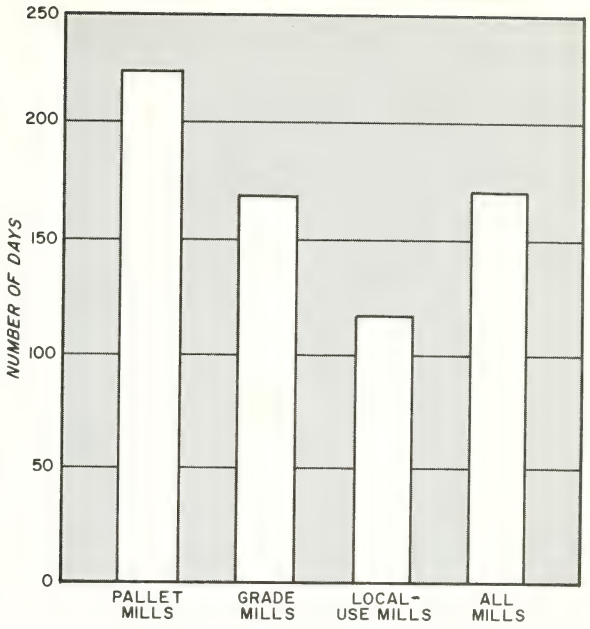

Figure 3.—Average number of working days per year, by mill type.

Employment and Operating Time

On the average, a grade-lumber mill employed 10 production workers; a pallet mill 6; and a local-use mill 5 (fig. 2). However, pallet mills reported the highest average number of working days per year, followed in order by grade-lumber mills and local-use mills (fig. 3). In terms of annual man-days of operation, an expression of both employment and days of operation, the average for all mills was 1,500 man-days, ranging from 650 man-days at local-use mills to 1,850 at grade-lumber mills (fig. 4).

The wide difference among mill types in number of operating days was attributed to effects of local work attitudes and to type of product produced. The number of non-operating days was greatest in the southeastern and south-central study areas of Kentucky (table 2).

In these areas, where the principal concentration of local-use and grade-lumber mills is found, absenteeism among mill workers is high during the winter. This may be a relic from the operations of earlier days when mills were smaller and were usually intended

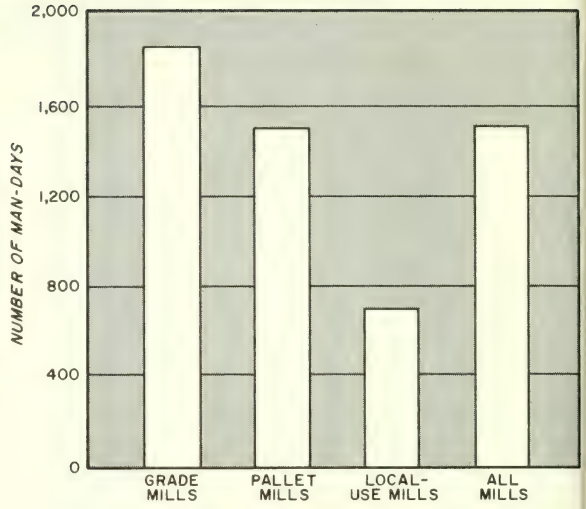

Figure 4.—Average number of man-days operated, by mill type.

to operate only part-time. It was natural then to shut down during bad weather when bottomless roads made travel difficult, and the discomfort of working in open-air mills and sloppy log yards reduced efficiency at the same time it increased the risk of illness and accident. By now, absenteeism during the winter seems to have become an accepted custom. Regardless of the reason, in these areas it is difficult today for a mill operator to assemble a full crew when he wants to operate during the winter season.

This labor problem is not so prevalent in northeastern Kentucky and southeastern Ohio, where most of the pallet mills are located.

Table 2.—Average annual number of non-operating days at study mills, by geographic area

Geographic area	Average annual number of non-operating days per mill
Southeastern Ohio	26
South-central Ohio	35
Northeastern Kentucky	20
South-central Kentucky	101
Southeastern Kentucky	108
All areas	79

Of course, labor in these mills can be used for pallet fabrication during bad weather.

Because the year of study was one of depressed hardwood lumber markets, it might reasonably be expected that this would be listed by operators as the primary cause for non-operating days. However, the primary reason given at all mills for not operating was poor working conditions related to inclement weather—low temperatures, muddy and slippery conditions in mill yards, and frozen logs. Poor weather was blamed for more than three-fifths of the non-operating days, while market lag was given as a cause for about one-tenth (fig. 5).

The operators do not consider lack of log supply as a major cause for non-operating days. However, it must be recognized that many mills did not operate at times because the mill's log suppliers could not produce logs under adverse weather conditions. Thus, as used here, log supply as a cause for non-operating days refers to those days when log suppliers failed to deliver logs for reasons other than weather conditions.

Raw-Material Procurement

Mill operators purchased their timber as stumpage or cut logs in almost equal quantities: 52 percent stumpage and 48 percent cut logs delivered to the mill. However, methods of obtaining logs differed substantially between the northern and southern por-

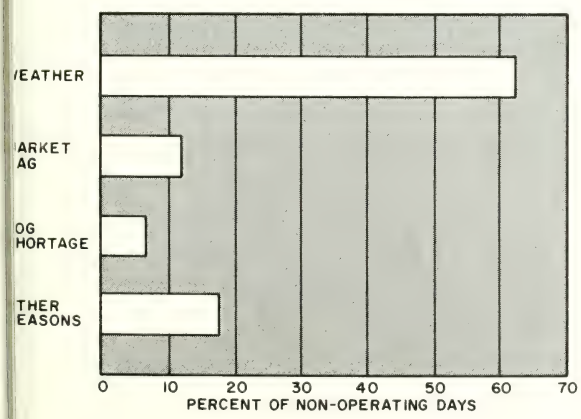

Figure 5.—Operators' reasons for non-operating days.

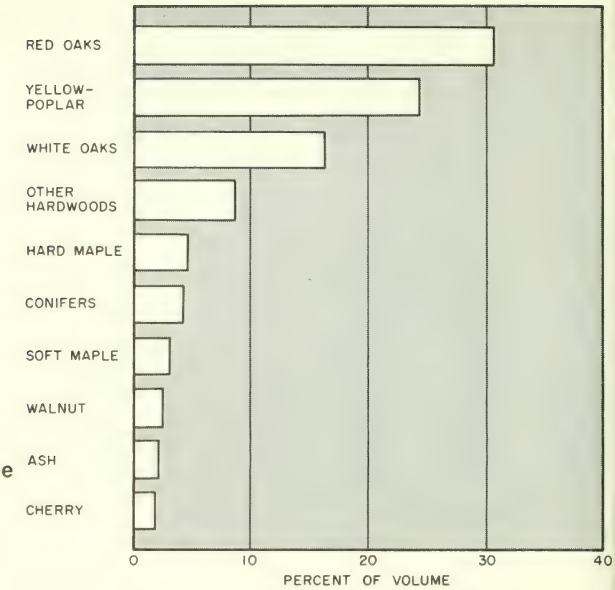

Figure 6. — Log volume purchased, by species.

tions of the study area. Mills in northeastern Kentucky and southeastern Ohio purchased 86 percent of their log volume delivered at the mill, whereas those in southeastern Kentucky bought only 17 percent of their logs on this basis.

The marked regional difference in methods of procuring logs between the northern and southern parts of the study area may be due to differences in timber-ownership patterns and timber accessibility. In the northern part of the study area, commercial forest land is usually divided among many small tracts, and a

Table 3.—Size of logs purchased, by diameter and mill type

Mill type	Percent of logs, by diameter inside bark at small end (inches) of—		
	Less than 12	12 to 20	More than 20
Grade-lumber	12	63	25
Pallet	44	48	8
Local-use	40	50	10
All mills	25	57	18

Table 4.—Distribution of volume output, by product and type of mill

Mill type	Percent of total volume							
	Grade lumber		Pallets & pallet lumber	Blocking	Dimension stock	Construction lumber	Local-use lumber	Total
	Green	Air-dry						
Grade-lumber	13	67	5	2	2	5	6	100
Pallet	11	3	58	12	8	2	6	100
Local-use	14	7	—	—	3	50	26	100

fairly well developed road network provides access to timber tracts. This environment is favorable to small independent logging enterprises.

By contrast, the southern portion of the study area is characterized by large individual timber holdings and relatively sparse road networks. This type of situation generally requires large capital outlays for timber harvesting, both for road construction and for acquiring title to timber. This generally discourages the development of small independent logging enterprises. As a consequence, mill operators in this region generally purchase stumpage and then let contracts for the logging and hauling.

Of the operators who purchase stumpage, two-thirds bought on the basis of a lump sum for the total volume of timber within a property boundary. The others used log-scale or mill-scale volume as basis for payment. Purchase of logs delivered at the mill yard was based almost exclusively on use of the Doyle rule for volume determination. Each mill operator used his own log-grading system or a modification of some existing log-grading system.

Yellow-poplar, red oaks, and white oaks accounted for 72 percent of the total volume of raw materials purchased by the study mill operators. Yellow-poplar was the single species most frequently purchased, representing one-fourth of the total raw-material procurement (fig. 6).

One-fourth of the logs purchased were less than 12 inches in diameter, inside bark, at the small end of the log; and less than one-fifth were over 20 inches (table 3). By mill types, about 2 out of every 5 logs at pallet and local-use mills were less than 12 inches d.i.b., whereas approximately 1 in every 10 logs at grade-lumber mills were in this size class.

Products and Markets

The 40 mills produced more than 52 million board feet of products for the year studied, and grade lumber alone accounted for 61 percent of the total product output (fig. 7).

Type of product produced varied among the three mill types, as would be expected because of the system used to classify mill types. Almost 60 percent of the total lumber volume produced at

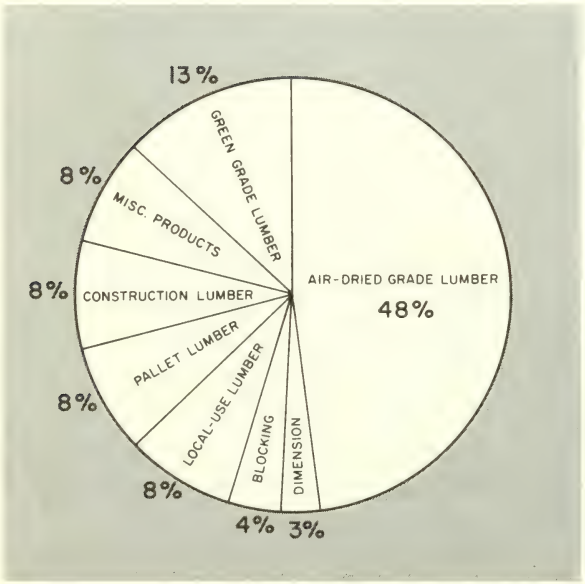

Figure 7.—Products of the mills studied.

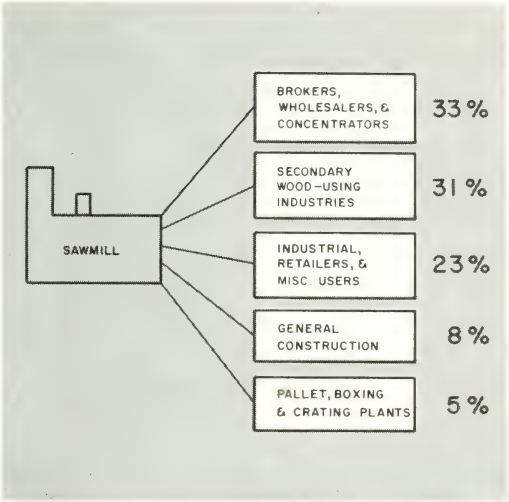

Figure 8. — The principal buyers of products from the study mills.

pallet mills was either sold as pallet lumber to pallet fabricators or was used in pallet construction at the producing mill. At grade-lumber mills, 80 percent of the output was grade lumber; and at local-use mills three-fourths of lumber produced was construction lumber or lumber sold for a variety of local uses (table 4).

The wholesale-broker-concentrator outlet and secondary wood-using industries were the principal buyers, accounting for nearly two-thirds of the product sales volume (fig. 8). Most mill output was sold between 50 and 500 miles from the mill location. Only 7 percent of the total product volume moved beyond 500 miles.

MILL PRODUCTIVITY

Annual Production

Annual lumber production for the study mills averaged 1,300,000 board feet, ranging from a low of 200,000 board feet to a high of 4,000,000 board feet. Average annual output amounted to 1,600,000 board feet at grade-lumber mills, 1,200,000 board feet at pallet mills, and 590,000 board feet at local-use mills (fig. 9).

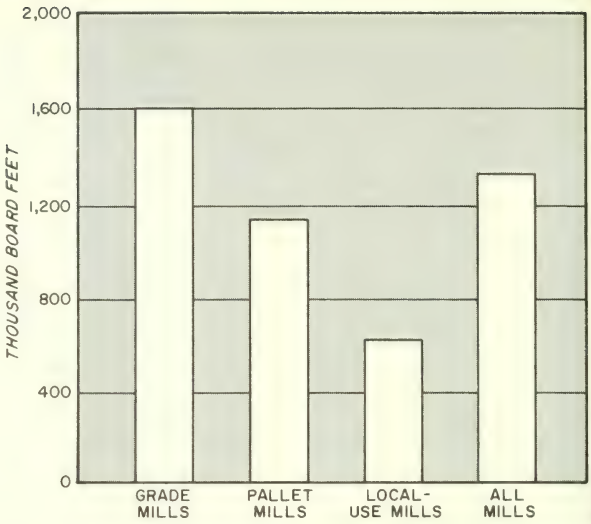

Figure 9. — Average annual lumber production, by mill type.

The rather wide variation in average annual output among mill types appears to be related largely to number of man-days worked. For example, grade-lumber mills operated almost 30 percent more man-days than pallet mills and produced about 40 percent more lumber products. Pallet mills operated about 120 percent more man-days than local-use mills and had about 90 percent more output. The fact that differences in average annual lumber production among mill types were not directly proportional to differences in average man-days operated is perhaps explained by the influence of other factors.

Man-Day Output

Lumber-product output per man-day averaged 920 board feet at local-use mills, 870 at grade-lumber mills, and 690 at pallet mills (fig. 10). Factors apparently accounting for higher labor productivity at local-use mills are: (1) most of the lumber is slash sawed which requires less log handling on the carriage than at mills where most of the lumber is sawed for grade, and (2) most of the lumber is sold ungraded, thus eliminating the additional handling required in end trimming, grading, and sorting.

Of the three mill types, labor productivity was lowest at the pallet mills primarily because production workers often serve in a dual capacity. Part of their time may be spent in lumber production, part in pallet fabrication.

Additional handling of lumber in operations such as end trimming and dipping contributes to lower productivity of grade-lumber mills.

Labor productivity, computed in terms of average value of product output per man-day, was highest at grade-lumber mills, where output value amounted to 78 dollars per man-day. By comparison, labor productivity at pallet and local-use mills averaged about 60 dollars.

Considerable variation in board-foot output per man-day occurred within each of the three mill types—500 to 1,330 board feet per man-day at local-use mills, 360 to 1,550 at grade-lumber mills, and 350 to 1,330 at pallet mills. Statistical analysis showed that variation in labor productivity was highly correlated with differences in milling equipment. Although labor productivity increased with increase in the number of pieces of equipment used, the log turner appeared to contribute most to productivity.

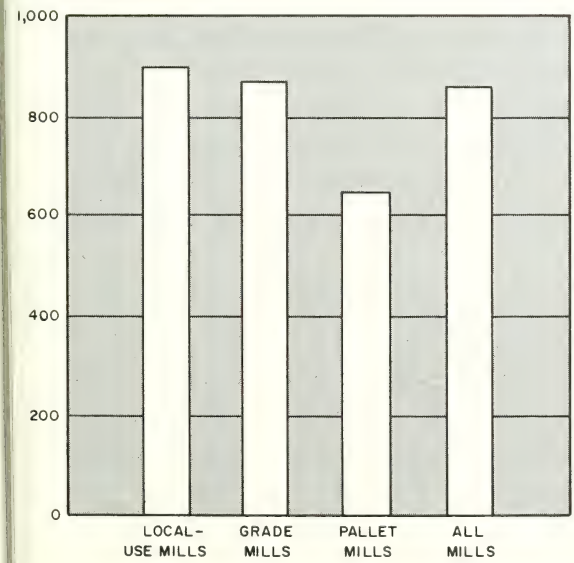

Figure 10.—Average lumber production per man-day, by mill type.

Almost half the variance in productivity was explained by the presence of this piece of equipment.

Tests were also made on the relationship between size of log sawed and labor productivity. The results showed that the proportions of logs sawed in the various log-size classes studied (table 1) were the same for mills of both low and high productivity. This should not be interpreted to mean that the size of log does not affect labor productivity. However, for the log-size classes studied, log size was not a significant cause for variation in labor productivity.

DISCUSSION & CONCLUSIONS

During the course of the study a number of production problems affecting milling efficiency were noted. At most mills, for example, it was observed that production was frequently delayed for various reasons. Often this would amount to no more than a few minutes for each occurrence. However, at some mills, equipment failure caused longer delays. In the aggregate, down time can greatly increase the annual lumber-production costs even though the down-time periods are short. Research to reveal the frequency and cause of production delays could lead to eliminating down time and reducing overall production costs.

Operators blamed poor working conditions associated with inclement weather as the major cause of non-work days. Draining and gravelling log and drying yards, wind-proofing and heating mill sheds, and providing indoor storage or at least storage on raised rollways for one day's log supply would improve working conditions and salvage many days of the present lost work time caused by bad weather.

Certain pieces of sawmill equipment contribute more to productivity than others. This suggests the need for studies of a type that will measure the contribution of various pieces of mill equipment to man-day output. Determining the profitability of investment in individual items of equipment could provide a good guide for improving mechanization throughout the industry.

A variety of grading systems was evident among mills buying

logs on a grade basis. There seemed to be no standardization; most frequently, the system in use was one developed by the mill operator himself. This suggests the need to evaluate the log-grading systems and log-pricing methods used by commercial sawmill operations.

It might be feasible for them to use the U.S. Forest Service standard specifications for hardwood factory lumber logs.[2] This is a grade system that relates log grades to lumber grades obtained from the log. It is now used by a number of hardwood sawmill operators in the East.

The maintenance of records for guidance in eliminating inefficient techniques and operating the sawmill as a business were, in general, poorly organized for most of the 40 mills investigated. The development of a simplified record-keeping system, specifically designed for maintaining records for the type of mills studied, could provide a basis for more accurate decision-making and better business management for the industry.

[2]United States Forest Products Laboratory. HARDWOOD LOG GRADES FOR STANDARD LUMBER. U.S. Forest Serv. Res. Paper FPL-63. 52 pp., illus. 1966.

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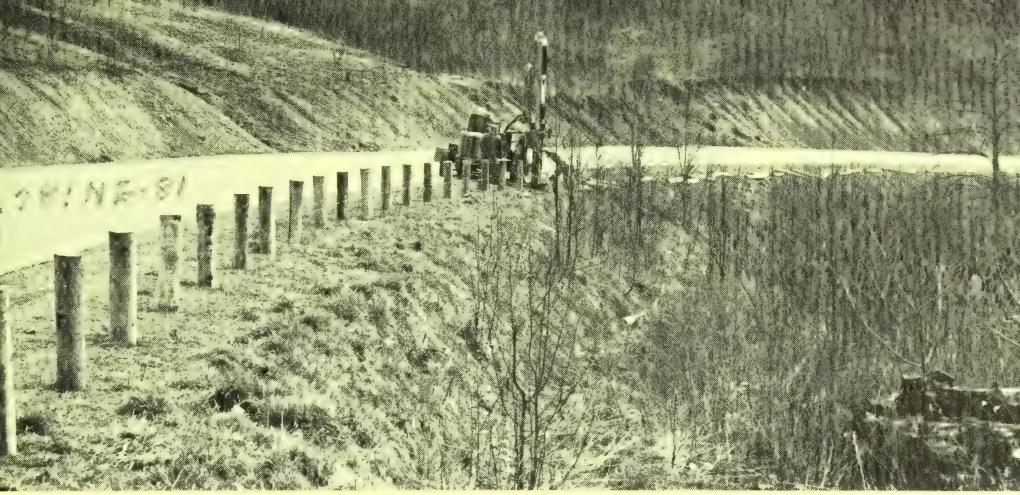

A way to reduce highway guardrail costs:

MACHINE-DRIVING of WOODEN POSTS

by Charles J. Gatchell

CLEMSON UNIVERSITY
JUN 12 1967
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U. S. FOREST SERVICE RESEARCH PAPER NE-81
1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

Acknowledgments

THIS study is the result of the efforts and cooperation of many people. Paul Craft and George Niskala, of the Forest Products Marketing Laboratory staff, contributed their knowledge to the development of the post driver. Niskala collected background information that greatly facilitated the research efforts. George Reeves, of Cross Lanes Construction Company, Nitro, West Virginia, allowed the needs of research to interrupt his production schedule with the result that a well-trained crew, with long experience in all types of post installation, was made available to operate the driving machine. Jack Harvey of the State Road Commission of West Virginia provided sites that represented typical installation situations in southern West Virginia.

A way to reduce highway guardrail costs:

MACHINE-DRIVING of WOODEN POSTS

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Why Wooden Posts?

WOOD is an excellent material for highway guardrail posts. When compared with other materials, wood has better strength characteristics,*(1, 2)* a lower initial cost, a lower cost per installed post, and—when pressure-treated with preservative —a service life of 30 years. Yet, in spite of these favorable qualities, wood is not often used for highway posts in new construction in West Virginia.

The critical problem is speed of installation.*(3)* Contractors prefer to use the type of posts that they can install most quickly. In recent years they have preferred steel posts because these can be set by machine. Wooden posts have traditionally been set by hand. In an 8-hour shift, 80 wooden posts can be set by hand whereas in the same time 240 steel posts can be driven by machine. At these rates, wooden posts cannot compete.

To find out whether the rate of setting wooden posts could be increased, staff members of the Forest Products Marketing Laboratory worked with a private guardrail contractor in devising a machine suitable for driving wooden posts. The result is a mobile post driver (figs. 1 and 2). This machine was used for installing posts on a variety of sites. Our studies showed that wooden posts can now be installed at competitive rates.

The Study

Purpose

This study was done to determine whether a finished line of guardrail posts could be installed rapidly with the new driver. For a realistic test, conditions typical of an actual guardrail post installation job were required. In addition to speed, it is necessary that guardrail posts be installed to specified tolerances. Therefore, posts were installed to meet the specifications of the State Road Commission of West Virginia for plumbness, alignment, spacing, and freedom from damage. Our main objectives in the study were:

- To compare the effectiveness of driving on a variety of sites.
- To compare the rates of installation by machine-driving and by the conventional hand-setting method.
- To evaluate the effect of post cross-sectional area on driving time.

Posts Used

The posts used were ordered with flat tops and bottoms, approximately 6 feet long, and pressure-treated with preservative. Some posts were delivered with uneven tops and bottoms. To see what effect such mismanufacture might have on driving, these posts were included in the study. Both softwoods and hardwoods were used.

The softwood posts were round, osmose-treated southern yellow pine. Post diameters were 6, 7, and 9 inches. The 7-inch size was chosen as the standard diameter and was used when comparing driving rates between sites. It was also used in a comparison of hand-setting and machine-driving on a single site. The 6- and 9-inch posts were used to determine the effect of cross-sectional area on driving time. All pine posts received two coats of white paint after installation.

The hardwood posts were sawed, creosote-treated red oak. Two sizes of posts were used: 6 by 6 inches and 6 by 8 inches.

All posts were installed to a depth of 3 feet as required by the State Road Commission of West Virginia. Driving to this uniform depth let us judge the resistance of the site; the longer it took to drive, the harder the site.

Sites Selected

Four sites, typical for southern West Virginia, were chosen with the cooperation of the State Road Commission. As these sites were on a well-traveled main highway, the Commission wanted the finished job to be pleasing to the eye of passing motorists. Therefore posts of different preservative treatments were not mixed on any given site.

Other restrictions were placed on post spacing and berm disturbance. As no guardrail was to be attached, the posts were spaced 8 feet apart The acceptable driven posts, once in place, were not disturbed.

Equipment and Manpower Used

The Forest Products Marketing Laboratory rented all necessary equipment and manpower from a commercial guardrail subcontractor.

The mobile post driver (figs. 1 and 2) consisted essentially of a post holder and hammer assembly mounted on the side of a tractor. To plumb the posts before driving, the assembly could be tilted plus or minus 20° at right angles to, or in the direction of, the line of posts. It could also be rotated 10°. The 1,368-pound hammer, automatically operated, hit a plate at the top of the holder at a rate of 30 strokes per minute. Final height adjustments were possible by manually controlling the length of stroke and rate of delivery.

The post driver was designed to be used with a 2-man crew. A driver-operator drove the machine from one post position to another, plumbed the post, and controlled hammer action. The other crew member was a laborer who loaded the posts into the post holder and helped the driver-operator center the posts at each location.

In the limited study of hand-setting, a 63-horsepower truck-mounted auger was used to drill 12-inch diameter holes. An air compressor, towed behind the truck, powered a hand-held earth tamper. In a commercial operation, five men are required to op-

erate this equipment: a truck driver, an auger operator, a laborer to help plumb the auger and set posts, and two laborers to backfill and tamp around the set posts.

This study was conducted with a crew of three men: a foreman, a machine operator, and a laborer. The men were well-trained and experienced in the techniques of driving steel posts and hand-

Figure 1.—A wooden post being installed with the newly developed driving machine.

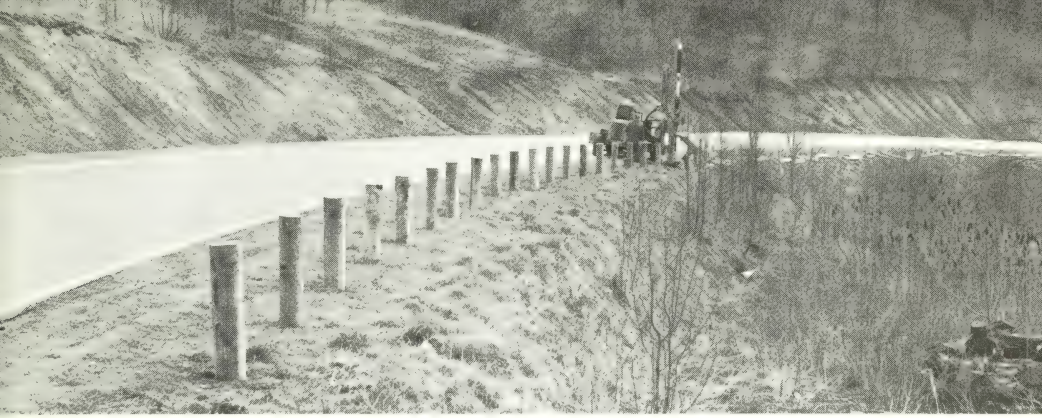

Figure 2.—A machine-driven wooden post installation on a curve in the highway.

setting wooden and concrete posts. Further, the crew was trained to use the new wooden post driving machine before the study was begun.

Factors Affecting Installation Time

In guardrail post installations, it is necessary to lay out the post line, mark the post locations, and distribute the posts along the site. The time spent is about the same regardless of the type of post or installing equipment to be used. Therefore these factors were not considered in this study.

Machine-Driving

In determining the rate of installation of guardrail posts by machine-driving, three time factors were chosen: driving time, setup time, and alignment time.

Driving time was recorded only when the machine was in automatic operation. Variations in driving time showed changes in the hardness of the site.

Setup time ran from the end of automatic driving on one post to the start of automatic driving on the next. Included here was the time to: (1) bring the post to specified height through manual control of the hammer; (2) disengage the post holder from the

post; (3) move to the next post position; (4) place the next post in the post holder; and (5) center and plumb the post. Most of the setup time was spent centering and plumbing the posts before driving. In preliminary tests we found that bringing the post to specified height through manual control of the hammer was rarely necessary and took less than 0.1 minute. Also, the total time to disengage from one post, move to the next position, and place the next post in the post holder was generally only 0.2 to 0.3 minute. All of these jobs were routine, and variations in setup time showed changes in crew efficiency.

Alignment time was the total time required to straighten any posts that were out of plumb. It began at the end of driving and included the time required to move along the line of posts. Straightening was done by nudging or pulling on each post with the post driver and tamping around the base of the post.

Alignment time varied not only with the number of posts requiring straightening but also with the severity of traffic. Positioning the post driver often required maneuvering in the middle of the highway. Sometimes it was necessary to wait for cars or trucks to pass. No timing adjustments were made for traffic delays as this was considered typical of most guardrail installation jobs.

Hand-Setting

When hand-setting, it is necessary to auger a hole, set the post, and backfill and tamp around the post. In the hand-setting test, the following times were recorded: (1) setup time; (2) augering time; and (3) post setting and tamping time. Setup time was defined as the time required to move from an augered hole to the next position with the auger ready for drilling. Augering and post setting and tamping times are self-explanatory.

Total hand-setting time was slightly more than normal as we wanted to examine each part of the hand-setting method. Under normal conditions, a certain amount of augering and post setting and tamping could be done at the same time. For our purposes, it was considered more desirable to examine each part of the hand-setting method. As this study was conducted with a 3-man crew rather than the normal 5- or 6-man crew, it was necessary to complete each step before the next step was begun.

Tests and Results

Tests 1A and 1B: Effect of Substrate and Berm Width on Driving Rates

Test 1A was made on a sloping curve cut in the side of a mountain (fig. 2). The face of the cut showed no large rocks or boulders and appeared to be mostly shale or gravel. The berm was wide, allowing a convenient layout of posts before driving and an ample working space for the crew between the post line and the berm edge. Fifty-four 7-inch southern pine posts were driven on 8-foot centers and 6.5 feet from the edge of the road surface.

Test 1B was made on a level fill in a valley on the other side of the mountain. The substrate appeared to be mostly gravel—probably hauled in by truck. The berm was very narrow, preventing a convenient layout of posts before driving. Also, the crew had only 1 to 2 feet of working space between the post line and the berm edge. Forty-five 7-inch southern pine posts were installed on 8-foot centers and 4.5 feet from the edge of the road surface.

The rates of installation on the two sites were about the same. Thirty posts per hour were set in test 1A on the wide berm (table 1) and 28 posts per hour were set in test 1B on the narrow berm (table 2). However, each site had a different effect on the time factors (driving, setup, and alignment times) used to calculate these rates.

Driving times in test 1A ranged from 0.4 to 1.6 minutes and averaged 0.7 minute per post. The change in site hardness was gradual. The driving times in test 1B reflected a more uniform and softer site. Driving time here ranged from 0.3 to 0.6 minute and averaged 0.4 minute per post.

The average setup time on the wide berm, at 1.1 minutes per post, was 0.1 minute shorter than on the narrow berm. The factors involved in the setup tended to balance each other. Centering and plumbing the posts were easier on the straight and level narrow berm, but loading the posts into the post holder was more difficult.

The total alignment time on the narrow berm was twice that on

Table 1.—*Seven-inch southern pine posts installed by driving: test 1A (wide berm)*

(All times in minutes)

Post number	Setup time	Driving time	Post number	Setup time	Driving time
1	0.8	0.7	30	1.1	1.0
2	.9	1.0	31	.9	1.4
3	1.1	1.2	32	.9	1.4
4	1.2	.7	33	1.2	1.4
5	.9	.8	34	1.1	1.1
6	1.1	.8	35	1.6	1.2
7	1.2	.7	36	1.4	1.4
8	1.1	.7	37	1.2	1.0
9	1.0	.6	38	1.1	1.6
10	1.1	.6	39	1.1	1.0
11	1.1	.5	40	1.2	.7
12	1.0	.5	41	1.1	.6
13	1.0	.6	42	1.1	.6
14	1.2	.5	43	1.2	.8
15	1.3	.5	44	1.1	.6
16	1.0	.4	45	1.3	.8
17	.9	.5	46	1.1	.6
18	1.0	.4	47	1.0	.4
19	.9	.5	48	1.1	.8
20	.9	.4	49	1.0	.4
21	.8	.4	50	1.1	.5
22	1.0	.4	51	.9	.7
23	1.1	.6	52	1.3	.5
24	.9	.5	53	1.0	.8
25	1.0	.4	54	1.2	1.2
26	.8	.5	Total	57.2	39.7
27	.8	.6	Average	1.1	0.7
28	1.0	.5			
29	.8	.7			

Alignment time = 11.5 minutes for 12 of 54 posts needing alignment after driving.

$$\text{Posts/hr.} = \frac{\text{Number of posts}}{\text{Total setup time + total driving time + alignment time}}$$

$$\text{x 60 min./hr.} = \frac{54}{57.2 + 39.7 + 11.5} \text{ x } 60 = 30$$

Table 2.—*Seven-inch southern pine posts installed by driving: test 1B (narrow berm)*

(All times in minutes)

Post number	Setup time	Driving time	Post number	Setup time	Driving time
1	1.6	0.5	24	0.9	0.3
2	1.6	.3	25	1.2	.4
3	1.3	.4	26	1.0	.4
4	1.0	.5	27	.9	.4
5	1.3	.5	28	1.0	.3
6	1.5	.3	29	1.2	.3
7	1.5	.3	30	1.6	.3
8	1.6	.3	31	1.1	.3
9	1.1	.4	32	1.4	.3
10	1.1	.4	33	1.4	.3
11	1.8	.6	34	1.2	.4
12	1.0	.5	35	1.0	.5
13	1.1	.6	36	1.0	.4
14	.9	.5	37	1.3	.4
15	1.0	.4	38	1.3	.3
16	1.1	.4	39	1.2	.4
17	1.4	.3	40	1.0	.4
18	1.0	.2	41	1.1	.5
19	1.0	.3	42	1.0	.6
20	1.4	.3	43	1.1	.6
21	1.1	.3	44	1.2	.6
22	1.0	.3	45	1.1	.6
23	1.0	.4	Total	53.6	18.0
			Average	1.2	0.4

Alignment time = 24.8 minutes for 15 of 45 posts needing alignment after driving.

$$\text{Posts/hr.} = \frac{\text{Number of posts}}{\text{Total setup time + total driving time + alignment time}}$$

$$\text{x 60 min./hr.} = \frac{45}{53.6 + 18.0 + 24.8} \text{ x 60} = 28$$

the wide berm. Much greater caution was needed in maneuvering the driver because traffic was moving very rapidly on this straight section of highway at the bottom of the mountain. Also, it is easier to align posts on a curve because the eye sees only a small portion of the total line. Small variations that could be seen easily when looking down a long straight line are not noticeable on a curve.

Test 2: A Comparison of Hand-Setting and Machine-Driving on a Single Site

A comparison of hand-setting and machine-driving was made next to the test 1A site. Thirty-eight 7-inch southern pine posts were installed on 8-foot centers and 9 feet from the edge of the road surface. To reduce the effect of site on the results, the hand-set posts were alternated with the driven posts. To allow a smooth production-type of installation, post driving was completed before hand-setting was begun.

The machine-driven posts were installed with an average time per post of 1.1 minutes for setup and 0.7 minute for driving. These results are similar to those of test 1A. This was expected because the sites appeared to be about the same.

At around 1 minute (table 3), there was no real difference between the setup times for hand-setting or machine-driving. However, it was of considerable importance that augering alone took twice as long (1.4 minutes versus 0.7 minute) as driving. The rate of installation for machine-driving was 29 posts per hour versus 13 posts per hour by handsetting. When all time factors were considered, it seemed safe to assume that the driving technique will be at least twice as fast as the hand-setting method with only half the number of men required.

Another important factor that favors driving in this comparison is the matter of site disturbance. Driving is a clean operation, causing no disturbance in the surface of the berm. However, when hand-setting it is necessary to smooth around each post and dispose of excess fill. The finished results of hand-setting are not so pleasing to the eye as those from machine-driving.

Test 3: A Comparison of Installation Rates for Two Sizes of Sawed Red Oak Posts

Test 3 was made on a site that was judged to be the most difficult of the series. As in tests 1A and 2, the site was located in a cut in the side of a mountain. Here, however, large boulders and rock outcroppings were visible in the face of the cut and on the

Table 3.—*Comparison of installation rates for hand-setting and machine-driving southern yellow pine posts: test 2*

(All times in minutes)

Hand-set posts					Machine-driven posts				
Post number	Setup time	Augering time	Post setting & tamping	Total	Post[1] number	Setup time	Driving time	Estimated alignment time	Total
1	2.2	1.2	2.4	5.8	1a	1.0	0.5	0.3	1.8
2	1.0	1.2	2.0	4.2	2a	1.0	.6	.3	1.9
3	.8	.9	2.7	4.4	3a	1.0	.9	.3	2.2
4	.9	.9	2.2	4.0	4a	1.4	.5	.3	2.2
5	1.0	1.0	2.8	4.8	5a	1.0	.8	.3	2.1
6	.7	1.0	2.7	4.4	6a	1.0	.7	.3	2.0
7	.7	1.6	2.2	4.5	7a	1.0	.5	.3	1.8
8	.7	1.2	2.4	4.3	8a	1.1	.7	.3	2.1
9	1.1	1.2	2.2	4.5	9a	1.4	.9	.3	2.6
10	1.0	1.6	2.5	5.1	10a	1.2	.6	.3	2.1
11	1.5	1.2	2.4	5.1	11a	1.2	.9	.3	2.4
12	1.1	1.9	2.6	5.6	12a	1.0	1.1	.3	2.4
13	1.1	1.2	1.9	4.2	13a	1.3	1.1	.3	2.7
14	1.2	2.4	2.6	6.2	14a	1.2	.5	.3	2.0
15	1.0	1.2	1.6	3.8	15a	.9	.7	.3	1.9
16	.9	1.5	1.4	3.8	16a	1.2	.6	.3	2.1
17	.9	1.7	2.0	4.6	17a	1.2	.6	.3	2.1
18	.8	1.8	2.3	4.9	18a	1.1	.5	.3	1.9
19	.7	1.4	2.8	4.9	19a	1.1	.7	.3	2.1
Average	1.0	1.4	2.3	4.7	Average	1.1	0.7	0.3	2.1
Posts per hour = 13					Posts per hour = 29				

[1]Not included are 38 posts for which only driving time was recorded. These times ranged from 0.3 to 1.1 minutes per post, with an average value of 0.6 minute per post.

Table 4.—*Rates of installation of 6-by-6-inch and 6-by-8-inch sawed red oak posts: test 3*

(All times in minutes)

6-by-6-inch posts			6-by-8-inch posts		
Post number	Setup time	Driving time	Post number	Setup time	Driving time
1	3.7	0.4	1a	2.2	2.1
2	3.4	1.0	2a	2.1	.9
3	2.8	.6	3a	2.0	1.1
4	2.5	.7	4a	2.4	3.2
5	1.7	.9	5a	1.9	1.5
6	1.4	1.3	6a	1.2	1.7
7	1.1	1.2	7a	1.3	1.9
8	1.5	1.2	8a	1.7	1.9
9	1.5	1.3	9a	2.3	2.3
10	1.6	1.3	10a	1.4	1.6
11	1.2	1.4	11a	1.5	1.7
12	1.4	1.3	12a	1.0	1.7
13	1.1	.9	13a	1.2	.6
14	1.5	1.0	14a	1.3	1.2
15	1.2	.8	15a	1.2	1.2
16	1.1	1.1	16a	1.5	1.2
17	1.1	.8	17a	1.3	.8
18	1.2	1.0	18a	1.3	.5
19	1.2	.5	19a	1.2	1.0
20	1.1	.8	20a	1.8	1.7
21	1.1	1.4	21a	1.1	1.8
22	1.2	1.1	22a	1.6	1.6
23	1.8	1.5	23a	1.6	1.3
24	1.0	.8	24a	1.2	1.1
25	1.2	1.0	25a	1.6	1.0
26	1.0	1.1	26a	1.3	1.3

Continued

side of the road shoulder. It was the judgment of the experienced crew foreman, both before and after the test, that neither augering or steel driving could be used here. Forty-one 6-by-6-inch and forty-one 6-by-8-inch creosote-treated red oak posts were set on 8-foot centers and approximately 12 feet from the edge of the road surface.

The driving times (table 4) show the unevenness and hardness of the site. Times ranged from 0.4 to 2.2 minutes for the 6-by-6-inch posts and from 0.5 to 3.8 minutes for the 6-by-8-inch posts.

Table 4.—*Continued*

6-by-6-inch posts			6-by-8-inch posts		
Post number	Setup time	Driving time	Post number	Setup time	Driving time
27	1.2	1.8	27a	1.0	1.5
28	1.0	1.2	28a	1.6	1.6
29	1.6	1.6	29a	1.1	1.6
30	1.5	1.3	30a	1.2	1.8
31	1.2	1.1	31a	2.8	2.9
32	1.4	1.2	32a	1.2	2.6
33	1.4	1.0	33a	1.2	1.6
34	1.3	1.5	34a	1.4	2.1
35	1.3	1.4	35a	1.8	2.7
36	1.1	1.6	36a	1.2	1.6
37	1.2	1.0	37a	1.2	1.3
38	2.2	1.6	38a	1.2	.9
39	1.4	1.7	39a	3.7	1.6
40	1.4	1.8	40a	1.3	3.8
41	2.5	2.2	41a	1.9	3.0
Totals	62.3	48.4	Totals	64.0	68.5
Average	1.5	1.2	Average	1.6	1.7

Alignment time = 69 minutes for 40 of 82 posts needing alignment after driving.

$$\text{Posts/hr.} = \frac{\text{Number of posts}}{\text{Total setup time + total driving time + alignment time}} \times 60 \text{ min./hr.}$$

6-by-6-inch posts:

$$\text{Posts/hr.} = \frac{41}{62.3 + 48.4 + 34.5} \times 60 = 17$$

6-by-8-inch posts:

$$\text{Posts/hr.} = \frac{41}{64.0 + 68.5 + 34.5} \times 60 = 15$$

Changes in these times were often abrupt, indicating that a large rock or a soft spot had been hit. With an average driving time of 1.2 minutes per 6-by-6-inch post and 1.7 minutes per 6-by-8-inch post, we found that driving time was almost directly proportional to cross-sectional area. The 6-by-8-inch posts had a one-third greater area than the 6-by-6-inch posts and took about one-third again as long to drive.

The setup times for this test were greater than those of the previous test. To insure proper post alignment with the 6-inch

face parallel to the road edge, a 6-inch wide U-shaped fixture was mounted in the post holder. The position of the fixture, which was 2 inches from the top of the holder, made post loading more difficult. Had the fixture been placed several inches lower, the setup times would have been reduced. The setup times averaged 1.5 minutes per post for the 6-by-6-inch posts and 1.6 minutes per post for the 6-by-8-inch posts.

It should be recalled that setup time included all times from the disengagement of the driver from one post through centering and plumbing of the next post. Occasionally, a post would be forced considerably out of plumb by rocks in the substrate. By digging around several of these, we found that the tilt was caused by large rocks that had been only partially moved from the path of the posts. A severe tilt made it hard to disengage the machine, and the resulting delay was included in the setup time of the next post.

Forty of the 82 sawed posts required some alignment after driving. The total time of 69 minutes was arbitrarily divided between the two posts sizes in calculating the rates of installation. In spite of the difficulties found here, only four posts could not be straightened to meet the specified tolerances.

The rates of installation of 17 and 15 posts per hour for the 6-by-6-inch and 6-by-8-inch posts were considered very good for this site.

Test 4: The Influence of Cross-Sectional Area on Driving Time

The results of test 3 had shown that driving time is almost directly proportional to post cross-sectional area. However, because the site was hard and this hardness varied sharply, we could not make comparisons between posts that were side by side. As only averages could be used, we felt it necesary to check these results.

Ten 6-inch and ten 9-inch southern pine posts were alternately driven on 3-foot centers in the berm adjacent to the test 1B site. The close spacing reduced the chances of site variation.

Table 5.—*Influence of diameter on driving time of southern pine posts: test 4*

(All times in minutes)

6-inch posts		9-inch posts	
Post number	Driving time	Post number	Driving time
1	0.5	2	0.9
3	.6	4	1.2
5	.4	6	1.0
7	.4	8	.9
9	.4	10	.9
11	.5	12	.8
13	.5	14	1.0
15	.5	16	1.0
17	.6	18	1.2
19	.5	20	1.2
Average	0.5	—	1.0

This test confirmed that driving time is directly proportional to post cross-sectional area. The 9-inch posts had about twice the cross-sectional area as the 6-inch posts and took twice as long to drive (table 5). On a commercial job, these differences (between 1.0 and 0.5 minutes per post) are very real. With the setup and alignment times of test 1B, the rate of installation would be reduced from 27 posts per hour (6-inch diameter) to 22 posts per hour (9-inch diameter) or a reduction of about 20 percent. Thus contractors should use the smallest acceptable size for greatest efficiency.

Discussion

Installation Rates

What rates of installation can a guardrail subcontractor expect when machine-driving wooden posts? Each job will vary and all time factors must be considered. The results of this study provide good guidelines. Any improvements in the design of the driving machine should increase the speed of installation.

Figure 3.—A commercial installation of sloped posts with guardrail attached.

Subcontractors measure production by the number of lineal feet of guardrail installed per 8-hour shift. They consider 2,000 lineal feet to be an acceptable minimum average when posts are spaced on 12-foot-6-inch centers—the present standard. On average sites, this requirement can be easily met by machine-driving.

In tests 1A, 1B, and 2, the installation rates of 28 to 30 posts per hour would result in about 3,000 lineal feet per 8-hour shift. If, by chance, the site hardness of test 1B had been found at the test 1A site, 3,600 feet per 8-hour shift could have been installed. These are very competitive rates.

The sawed-post installation rates of 15 to 17 posts per hour would produce 1,500 to 1,700 lineal feet of guardrail per 8-hour shift. As steel posts could not be driven nor could an auger be used on the site, these rates were considered to be highly acceptable.

The Posts

In all tests, there were several mismanufactured posts that did not meet order specifications. The most common failings were slopes in the tops and/or bottoms. In general, posts with sloped tops were not visibly damaged by driving. The tops were flattened until about one-third of the top area was in contact with the plate at the top of the holder. As seen in a subsequent production installation (fig. 3) sharply sloped posts can be driven free of damage when a sloped insert is used to distribute the load on the post top.

No tapered posts were included in this study. However, driving posts with sloped bottoms (greater than 1 inch in 7 inches) led us to conclude that tapered posts would not be desirable. The sloped posts tended to drift toward the long side. This drift became more noticeable on the rockier sites. Also, as the blunt-ended posts could be rapidly driven, the cost of tapering may not be justified.

Cost Factors

What is the cost of machine-driving a wooden post compared to the cost of hand-setting wood or driving steel? The important factors in this comparison are post prices and labor costs. The costs of an auger, a steel-post driver or a wooden-post driver are about the same and can therefore be ignored.

The cost of labor per installed post depends on the number of posts installed per unit of time and the number of men required. The typical machine-driving crew for wooden posts consists of a foreman, a driver operator and one laborer, at a total cost of about $10.60 per hour. Based on an installation rate range of 15 to 30 posts per hour, the setting cost per post of driven wood is $0.70 to $0.35. Table 6 allows a cost comparison of driven and hand-set pressure-treated wood and driven galvanized steel. The total cost per wooden post installed by driving is at least $1 less

Table 6.—*Comparative installation costs of driven wood, hand-set wood, and driven galvanized steel posts in West Virginia*

(In dollars per post)

Item	Driven treated wood	Hand-set treated wood[1]	Driven galvanized steel[1]
Purchase price[2]	2.75—2.79[3]	2.75—2.79[3]	5.25—5.85
Setting	.35— .70	1.87—2.35	.35— .52
Total	3.10—3.49	4.62—5.14	5.60—6.37

[1] Source: Lindell, Gary R. MARKET OPPORTUNITIES FOR TREATED WOODEN GUARDRAIL POSTS IN WEST VIRGINIA. U. S. Forest Serv. Res. Note NE-36, 6 pp., 1965.
[2] Delivered to the installation site.
[3] Includes costs of sloping and drilling.

than by hand-setting; it is $2 to $3.30 less than the cost of driven galvanized steel.

The post driving machine should also be useful in highway district maintenance programs. These programs call for removing and replacing old or damaged posts or adding new, short sections. The driver can be driven from job to job at speeds up to 30 miles per hour. It can be used to pull as well as set posts. With this versatility, the machine should be economical in this use.

Conclusions

In applied research, it is sometimes difficult to give hard and fast rules based on the results. For any given post-installation job, differences in men, equipment, driving sites, or other factors might alter the rates of installation found in this study. However, it is possible to indicate what can be expected.

Because of desirable strength characteristics, long service life, and low cost, pressure-treated wooden guardrail posts are completely acceptable and in many ways preferable to posts made from other materials. With the introduction of machine-driving, the rate of installation of wood is now competitive with that of machine-driven steel. The results of this study allow the following conclusions to be made:

- Wooden posts can be driven on any site where steel posts can be driven. They also can be driven on some sites where steel cannot and where an auger cannot be used.
- On sites free of large rocks or other obstructions, guardrail subcontractors can expect to install around 2,500 lineal feet of guardrail line per 8-hour shift with the type of equipment used in this study. A maximum of around 3,500 lineal feet can be expected.
- On the same site, posts can be set at least twice as fast by machine-driving as by hand-setting. The subcontractor can save $1 to $2 per installed post by machine-driving.
- The installed cost of machine-driven wooden posts is $1 to $3.25 less than that of driven steel.
- For machine-driving, posts with blunt bottoms are preferable to those with slopes.
- The driving action will cause no damage to the tops of properly machined wooden posts.
- Wooden-post driving time is about directly proportional to cross-sectional area—the greater the cross-sectional area, the longer the driving time.

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FOREST COOPERATIVES

A Bibliography

compiled by
Gilbert P. Dempsey

U. S. FOREST SERVICE RESEARCH PAPER NE-82
1967
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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FOREST COOPERATIVES

A Bibliography

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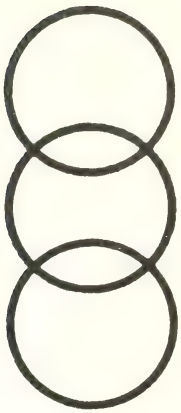

INTRODUCTION

THIS bibliography is a comprehensive listing of domestic articles and research papers, as well as foreign research papers, about forest cooperatives. The compilation was made in conjunction with and as a byproduct of a formal socio-economic analysis of forestry associations. The articles conern, directly or indirectly, the activities of cooperative associations formed by forest landowners to market timber and timber products.

One section contains selected references to recent literature about the economics of cooperatives. Though these publications describe neither forestry cooperatives nor primary industry marketing problems, an understanding of the theoretical and legal aspects involved and a knowledge of alternative marketing methods — as exemplified by comparable organizations — are of utmost importance to any serious consideration of the cooperative business enterprise.

This bibliography is a sequel to *Cooperative Marketing of Forest Products,* compiled in 1939 by Mildred B. Williams, U. S. Forest Service librarian. The author is indebted to Miss Williams for her comprehensive research of literature for the years prior to 1939. Without her help this paper would be seriously deficient.

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NEEDED: MORE REGENERATION

EASTERN HEMLOCK is an important cover species for ruffed grouse, turkeys, deer, snowshoe hares, and rabbits. The extensive range of hemlock in the Northeast and its silvical characteristics of shade tolerance, relatively slow growth, and feathery full foliage *(Hough 1960)* make it unequaled in value among our native conifers as a shelter species for game. Mixed woods of young hardwood-hemlock are reported to be the best all-purpose grouse cover, and all-age groups of hemlock comprising 20 to 70 percent of the crown cover provide food and shelter for all seasons — although the use of this cover type by grouse is slight in summer *(Edminster 1947)*.

The history of hemlock for the past several decades includes widespread cutting without replacement in the stand, mortality of young trees from wildfire, and elimination from stands where it competes for space with commercially more valuable hardwood species. One of the most effective deterrents to the natural regeneration of hemlock in recent times is the mortality of seedlings from deer browsing in areas of high deer populations.

These factors, when added to that of the rather rigid moisture requirements of hemlock for germination and early growth *(Olson et al. 1959)*, have reduced its abundance and effective density for forest game in many areas of the Northeast.

The reduction in hemlock density is most striking in the northern hardwood type of Pennsylvania. For example, on the Allegheny National Forest the deficiency of hemlock and other conifers is an important obstacle to habitat management for

Figure 1. — A savanna-type stand in the study area in the foreground. Tree and shrub reproduction in this type is heavily browsed by deer.

grouse and other small game species *(U. S. Forest Service 1963)*. In areas like this there has been very little natural re-establishment of hemlock — nor is re-establishment very likely to happen as long as deer populations remain at their present high level.

But artificial seeding or planting to re-establish hemlock for grouse cover may be a justifiable alternative to natural regeneration if it is done in selected areas — even if the seedlings must be protected from heavy deer browsing. Should such a program be considered, important prerequisites in planning should include not only the selection of areas that have a good potential as grouse habitat, but also the selection of sites within these areas that are favorable for the growth of hemlock.

This is a report on the results of seeding and planting tests with hemlock under different aspects, stand types, and site preparation to determine what conditions are most favorable for articial regeneration.

THE STUDY

Location

The tests were made in a 400-acre study area in the northern hardwood type on the Allegheny National Forest in northwestern Pennsylvania. Much of the study area is in hardwood poletimber stands, except for a grading-off from these stands to orchard-type poletimber stands and an open savanna type of vegetation.

The poletimber stands are mostly 20 to 60 years old. Approximately 68 percent of the total forest acreage is in these stands. There is no formal definition for the orchard type; it is understocked with trees that are generally of poor form, and the understory is primarily a mixture of grasses and forbs that persist for many years. The ground vegetation receives shade from the overstory for some part of each day. The savanna type of stand has scattered distribution of trees and shrubs on the lower slopes and up through several of the side drainage areas (figs. 1 to 3).

Figure 2. — An orchard-type stand showing young, poorly formed black cherry trees. Many orchard stands are more thinly stocked than this one.

Figure 3. — A hardwood poletimber stand in the 20-40-year-old age class. Such stands provide little shelter for grouse.

Approximately 45,000 acres on the Allegheny National Forest and 95,000 acres in both state and federally administered forests in the Allegheny Plateau of northwestern Pennsylvania are in the savanna and orchard types. The savanna type and the more thinly stocked stands in the orchard type are choice fawning areas for deer as well as preferred brood range for ruffed grouse and turkeys. Cottontails and snowshoe hares also frequent such areas as a source of food in preference to closed-canopy forests. These areas, when occurring in blocks of more than a few acres, have been generally regarded as problems in growing timber. But the value of many of these areas for wildlife may outweigh the loss in potential production of wood fiber.

Source of Seeds and Seedlings

The seed source for the tests was the Nepaug State Forest in northwestern Connecticut. The viability of the seed was estimated by the supplier to be 65 percent. The seeds were moistened and stratified for 35 days after delivery in polyethylene bags at

temperatures of 36° to 40° F. This brief period of stratification probably resulted in some improvement in the rate of early germination. Olson *et al. (1959)* recommended stratification for 2 to 3 months.

The hemlock seedlings, 5 to 9 inches high, were 3-0 commercial stock from a western Pennsylvania nursery. Seedlings were transferred upon delivery to cold storage, from which the daily planting supply was withdrawn.

Experimental Design and Methods

Three aspects (north slope, south slope, and bottom) were selected for seeding and planting tests. There were three blocks for each aspect, and each block contained three stand types (savanna, orchard, and poletimber). Each stand type was randomly selected from those available at each block location.

In each savanna and orchard stand, one planting-site treatment was assigned at random to one of two plots. One plot was rototilled to a depth of 12 to 16 inches in a circle about 2 feet in diameter at the planting spot to break up the soil and eliminate the deep sod, and thus reduce the competition of other species with the seedling. The other plot was left undisturbed. No ground treatment was applied in the poletimber stands. Instead a single plot was left untreated in each stand.

The seedlings were planted in five rows of six seedlings each at a spacing of 6 X 6 feet. A mattock was used to form the planting hole.

Single seed spots, about 6 feet square, were also rototilled in the open and orchard types. The seed spot in the poletimber was lightly raked clear of undecayed leaves. A total of 500 seeds was broadcast on the seed spot.

Seeding and transplanting were done during the first week of May 1963. The number of germinates and the number of seedlings surviving were determined in mid-July, and both seedling survival and height growth were measured in mid-November 1963. Observations in selected blocks were continued through 1966.

Objectives

The study was designed to test the following null hypotheses:

- That there would be no significant difference in the effect of aspect and stand type on the number of first-year germinates on the treated seed spots in the open and orchard types.
- That there would be no worthwhile differences in the number of first-year germinates on the raked seed spots in the pole-timber type and the number on the rototilled spots in the open and orchard types.
- That there would be no significant differences in the effect of ground treatment on the survival and height growth of seedlings planted in the open type and seedlings planted on the orchard type within each combination of aspect and stand type.
- That there would be no significant difference in the effect of aspect and stand type on the survival and height growth of seedlings in the untreated spots in all of the stand types and aspects.
- That there would be no significant difference in the effect of aspect and stand type on the survival and height growth of seedlings in the rototilled spots in the open type and seedlings in the rototilled spots on the orchard types in all of the aspects.

Analysis

The analysis planned for comparing the results of the seeding experiment was found to be unnecessary, and only inspection of the data was required for drawing conclusions.

The design of the experiment for comparing the effects of ground preparation on the survival and height growth of seedlings provided for a separate analysis of variance for a randomized-block design for each of the six combinations of aspect and stand type (open and orchard):

Source of variation	*d.f.*
Total	5
Block	2
Ground treatment	1
Error	2

For comparing the effect of aspects and stand types on the survival and height growth of seedlings the design provided for the analysis of variance using the three untreated plot observations within the nine aspect-stand type combinations:

Source of variation	*d.f.*
Total	26
Aspect	2
Error (a)	6
Stand type	2
Error (b)	16

Aspects and stand types (open and orchard) were again compared by analysis of variance, using the two rototilled plot observations within the six aspect-stand type combinations:

Source of variation	*d.f.*
Total	17
Aspect	2
Error (a)	6
Stand type	1
Error (b)	8

The 5-percent level of significance was specified in testing the hypotheses about statistical differences in the yield of germinates and in seedling survival and height growth.

Statistical inferences from the study were limited to the experimental area and, in a more strict sense, to the particular aspects and stand types where seeding and planting were done. The conditions of the study appeared to be representative not only of those on the study area, but also of those in the northern hardwood type on the Allegheny National Forest. Thus general inferences drawn from the results of the study can be applied to the Forest. And they should also find application in other areas of the Northeast where there are similar stand types or conditions.

RESULTS AND DISCUSSION

Seeding

The rate of germination and the yield of germinates in each of the three stand types in all aspects were low (table 1). Seeding in savanna areas after rototilling was a complete failure. Rototilling may even have had an adverse effect on germination by exposing the seeds to earlier drying. Success was only slightly better in the orchard type, where the overstory provided shade for a part of the day. However, by late summer it was too difficult to locate germinates in the open and orchard seed spots to have confidence in the results. By the second growing season after seeding, a rank growth of sedges had invaded each spot and apparently had completely captured these spots.

It is doubtful that success would have been better had no ground treatment been applied, because the density of the undisturbed vegetation and the thick sod present a rigorous environment for a species so demanding in its moisture requirements.

The hypothesis that there would be no worthwhile differences in the number of first-year germinates on the raked seed spots

Table 1. — *Yield of germinates per acre and rate of germination in hemlock 2 months after seeding in spots at the rate of 4½ pounds per acre*

Aspect	Stand type			Average	Rate
	Open[1]	Orchard[1]	Pole[2]		
	No.	*No.*	*No.*	*No.*	*Percent*
North	0	4,400	34,100	12,900	2.1
South	0	8,900	12,500	7,100	1.1
Bottom	0	1,200	15,800	5,700	.9
Average	0	4,800	20,900	8,600	—
Rate (percent)	0	0.8	3.3	—	1.4

[1] Seed spots rototilled.
[2] Seed spots raked.

Table 2. — *Percent of survival in hemlock seedlings 6 months after transplanting in different stand types and aspects without ground preparation*

Aspect	Stand type			Average
	Open	Orchard	Pole	
North	93	100	96	97
South	92	96	98	95
Bottom	92	91	92	92
Average	92	96	95	—

in the poletimber and the number on the rototilled spots in the open and orchard types was partially disproved.

Relative success was encountered in seeding in the pole stand type where the spots were lightly raked to expose the humus. The production of about 34,000 germinates per acre on the north slope in this type was more than twice that on the south slope and bottom, although the germination rate was only 5.6 percent. But general observations of these seed spots in the pole stands during the second year showed that most of the small hemlocks had disappeared.

Seeding immediately after the disappearance of snow cover, possibly in early April, and with a longer period of seed stratification, would be preferred over the methods used here, in which stratification was limited to 35 days and seeding was delayed until May.

Seedling Survival

The overall survival rate of seedlings when measured 2 months after planting was 98 percent. By mid-November the overall surival rate was 95 percent. The ground treatment had no significant effect on the rate of survival of seedlings planted in the open type and in seedlings planted in the orchard type within each of the three aspects.

The aspect and stand type did not affect the survival rate appreciably. The rate of survival on the untreated plots was 94

percent. Among these plots, the greatest difference in survival rates between aspects and between stand types was 5 percent and 4 percent, respectively. None of these was found to be significant. The highest survival rate (100 percent) was found in the orchard type on the north aspect.

On the treated plots, the overall survival rate was 96 percent. Again, survival was only 4 percent higher in the orchard type than in the open type. There was virtually no difference in the survival rates between aspects.

Seedling Height Growth

The pattern of height growth of the seedlings in general followed that of the survival rate. When measured in mid-November, there was no significant difference between the height growth of seedlings on the rototilled plots and those on the check plots within any of the six combinations of a single stand type and aspect. But inspection of the height-growth data for these six comparisons showed that although the difference in each case was small and unimportant, there was an opposing consistency in the difference within stand types:

Stand type	*Average height growth*	
	Check (feet)	*Rototilled (feet)*
Open	0.72	0.69
	.65	.60
	.67	.69
Orchard	.65	.89
	.75	.79
	.72	.73

As shown above, in two out of three instances in the open type, the removal of the competing vegetation by rototilling resulted in less growth than that of seedlings on the check plots. Probably any benefit from the elimination of competing vegetation was offset by the harmful effects of full exposure of the seedlings to sunlight and subsequent drying. But in all instances of rototilling in the orchard type, the growth of seedlings was greater than the growth of those on the check plots. The com-

Table 3. — *First-year height growth for hemlock seedlings transplanted without ground preparation in 3 stand types within each of 3 aspects*

Aspect	Stand type			Average
	Open	Orchard	Pole	
	Inches	*Inches*	*Inches*	*Inches*
North	8.7	10.2	8.4	9.1
South	8.0	8.7	8.8	8.5
Bottom	7.8	9.0	8.4	8.4
Average	8.2	9.3	8.5	8.7

peting vegetation was removed as in the open stand, but the orchard stand provided enough cover foliage to prevent the sunlight from drying the seedlings.

Although the differences between the height-growth data for ground treatments were not statistically significant, the data were not combined because of the apparent interaction of the effects of eliminating the competing vegetation and the effects of increasing light intensity and high temperatures. Of the two effects, light intensity seems to have the greater influence on the growth of hemlock seedlings.

When compared among aspects, the average height growth of seedlings on the untreated plots was greater on the north slope than on either the south slope or on the bottom (table 3) but the difference was not significant. The difference in growth of seedlings between the south slope and the bottom was negligible.

Among the stand types, the growth of seedlings was significantly better in the orchard type (table 3). There was no worthwhile difference in height growth between the open and pole-stand types. The highest growth rate (10.2 inches) occurred in seedlings in the orchard type on the north slope. Apparently this combination of stand type and aspect provided the most favorable conditions of partial shade from the overstory and a reduced daily period of direct sunlight, both resulting in optimal light and temperature conditions.

The height growth of seedlings on the rototilled plots in the open and orchard types for all aspects followed approximately the same pattern as that on the untreated plots. Growth was significantly better in the orchard type (9.6 inches) and highest in the seedlings on the north slope in this type (10.7 inches), although the latter difference was not significant.

Supplementary Observations

The depth of color of the foliage of seedlings was strikingly different among the three stand types. It varied from dark green in the pole stands to a lighter green in the orchard type to a pale green or a chlorotic yellow-green in the open.

These differences in color indicate that the similarity in average height growth between seedlings in the open and pole stands (table 3) was the result of a coincidence in the effects of opposing factors. In the pole stand, the relatively slow growth probably was due to environmental conditions of a good moisture supply but heavy shade, while in the open type slow growth was probably the result of full exposure to light, but accompanied by higher temperatures and excessive drying. The best balance between moisture, temperature, and light for the seedlings apparently occurred in the orchard type.

The seed spots were re-examined 3 years after seeding, before the annual regrowth of sedges and grasses reduced the accuracy of seedling counts. The examination confirmed the earlier finding that seeding failed completely in the open type. And, as expected, there was a high rate of loss (90 percent) in seedlings in the poletimber type in all aspects.

But contrary to expectations, the number of seedlings in the orchard type had increased from the initial average rate of 4,800 germinates per acre to 6,400 per acre. All of this increase occurred within the north and south aspects. The yield in these two aspects was 6,000 and 12,100 seedlings per acre, respectively — a high rate of density after 3 years and possibly enough to justify consideration of seeding as a management procedure in restocking hemlock.

Although the increase that occurred in the number of seedlings

may have been due to some natural seeding into the seed spots, it is more likely that germination from the initial seeding was delayed until the second and third growing seasons.

Hazards

One hazard in planting hemlock in open areas—except on north-facing slopes—occurred in the first year after a late heavy frost. The frost came after the first surge of spring growth, with the result that the new foliage on the twig tips thawed rapidly in the full sunlight and browned-off in varying amounts in 52 percent of the seedlings located on the south slopes and bottoms. Only 7 percent of the seedlings on the north slope were so affected.

By the fall season after planting, it was apparent that the seedlings would have to be protected from deer browsing; the incidence of browsing for all locations by November averaged nearly 14

Figure 4. — Protection against heavy deer browsing by fencing is necessary to establish hemlock cover for grouse on the Allegheny National Forest. This fence protects an experimental planting of hemlock in an orchard-type stand.

percent. Galvanized 21-wire poultry fence, 58 inches high, was erected at this time around all plots within four of the nine blocks in the study (fig. 4). Trees were used instead of metal posts whenever convenient. In November 1964, one year later, the incidence of deer browsing on seedlings in the unprotected plots had risen to 42 percent.

The height growth of hemlock protected from browsing on the untreated plots followed a pattern like that found in the first year after planting. The average growth for all of these seedlings was 8.2 inches. The best growth (11.5 inches) was again attained in the orchard stand on the north slope. The poorest average height growth (6.6 inches) occurred in the open plots for all aspects.

Survival rates for the fenced and unfenced seedlings, regardless of ground preparation, were determined in June 1965, approximately 2 years after planting (table 4). The survival rate for all seedlings protected from deer browsing was highest in the orchard type and lowest in the open type. The differences in rates of survival between protected and unprotected seedlings were

Table 4. — *Percent of survival in hemlock seedlings protected and unprotected from deer browsings during the second year after planting in different stand types and aspects*

Item	Protected[1]	Unprotected[1]	Loss from deer browsing
	Percent	*Percent*	*Percent*
Aspect:			
North	77	66	11
South	79	77	2
Bottom	87	62	25
Stand type:			
Open	64	50	14
Orchard	94	88	6
Pole	88	86	2
All	81	72	9

[1] Averages from 4 blocks.

attributed to mortality from deer browsing. The loss of seedlings from this cause appeared to be highest in open areas in the bottom.

In late 1964, two management-size plantings of 3-0 hemlock seedlings were made in the orchard type on the study area. A spacing of 10 x 10 feet was used. The dimensions of the areas were 100 x 330 feet and 100 x 470 feet. The following year both areas were fenced with the same material that was used to protect the experimental plantings. Erected by management personnel, the direct cost per foot of fence, including labor and materials, was 28 cents. The total cost of fencing the smaller planting was $241.00; the cost for the larger one was $319.00.

Costs

The cost of seed used in the study was $45.00 per acre. This is derived from a cost of $10.00 per pound for seed collection, and seeding in the study at a rate of 4½ pounds per acre.

Planting costs may be competitive with the cost of seeding; the results of planting may be more predictable, and planting may impose fewer restrictions on the choice of sites. In a recent machine-planting of seedlings of mixed species on the Allegheny National Forest, the cost per acre of planting 125 acres was $44.25. This included all direct costs. Hand-planting costs are not known, but it is expected that they would be higher. Hand-planting of hemlock for grouse cover would be required in poletimber stands and in most orchard-type stands because of the difficulty of maneuvering machine equipment.

CONCLUSIONS

The high survival and growth rates of hemlock seedlings planted in the orchard type — and the report by Edminster *(1947)* that a mixture of hardwoods and hemlock is the best all-purpose type of grouse cover—indicate that the orchard type is the first choice among the three stand types for the re-establishment of hemlock. cover. The higher growth rate in this type is clearly an advantage in establishing effective cover in the shortest time. The rates of annual growth found in this study indicate that useful cover for grouse would be available about 5 years after planting,

or when the trees are about 5 feet high. Roosting cover would be available about 3 years later when the trees reach a height of 7 to 8 feet.

The minimum spacing suggested in planting seedlings in the orchard type is about 10 x 10 feet (435 stems per acre) to allow the retention of foliage on the lower branches. The size of planting area need not be large; it is suggested that the form be rectangular, about 100 feet wide and not less than 300 feet long. Grouse tend to utilize the exterior margins of coniferous cover but probably require the security of at least 300 feet in which to move when disturbed.

The number of such blocks that would be required, as well as their distribution in a unit of grouse range, will depend upon the size and arrangement of other essential habitat components, a subject outside the scope of this report. It should be emphasized that a planting program for hemlock permits considerable flexibility in the choice of sites within the stand type, and hand-planting of hemlock is required to preserve this flexibility, and indeed to increase it.

The survival, growth rates, and appearance of hemlock seedlings planted in the poletimber stand make this type the second choice for cover establishment. The advantage of having a higher proportion of hardwoods in the future hemlock-hardwood stand might well make it a first choice, although some degree of thinning of the hardwoods several years after planting would be necessary to release the hemlock and preserve the full growth of foliage to the ground level. A suggested spacing of seedlings in this type is about 12 x 12 feet (300 stems per acre) to accommodate the inclusion of a large number of hardwood stems. The minimum width should be about 100 feet — the same width suggested for the orchard type.

The selection of either the orchard or poletimber type — or both — for planting will depend upon their availability, size, and distribution in relation to other essential habitat components in the area selected for cover establishment.

There seems to be little necessity to utilize openings for planting hemlock cover. The tests in this study gave marginal to poor

results. Also, the advantage of having a mixture of hemlock and hardwoods would be lost by solid plantings of hemlock in this type.

It is expected that other game species would also benefit from the establishment of hemlock cover. Therefore the cost of establishment may be justifiably distributed in proportion to the increase in benefits to other species if these benefits are desired. Equally important, the cost of planting should be allocated to the total area improved or made more attractive to grouse because of the establishment of cover. For example, a 1-acre planting may result in an increase in use by grouse of 60 acres in the vicinity of the new cover planting.

Seeding of hemlock in the orchard type under the conditions of this study gave encouraging results, especially in stands on the south aspect. But longer stratification of seed to hasten germination, and seeding early in the spring—especially in poletimber stands — should be tested before a judgment is made about the success of this method for establishing hemlock cover.

Where deer browsing pressure is high, seedlings should be protected from deer browsing. Fencing costs per unit of cover established may be justified if cover is the limiting factor and intensive management for grouse is a planned objective.

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RADIATION MEASUREMENTS

by various instruments in the open and in the forest

U. S. FOREST SERVICE RESEARCH PAPER NE-84
1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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RADIATION MEASUREMENTS by various instruments in the open and in the forest

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Importance of Radiant Energy

THE RECENT REVIVAL and intensification of interest in radiant energy in the forest has developed partly from a better understanding of the close relationship of radiant energy to the physiological processes that govern tree growth and transpiration. There is also a growing appreciation among foresters that forest-streamflow relationships are governed mainly by the interaction of forest cover and radiant energy.

This interest has been stimulated by the recent invention of inexpensive instruments that permit the measurement of various portions of the energy spectrum. Shortwave instruments cover the wave-length range from 0.3 to 4.0 microns and measure both beam and diffuse components of solar radiation; longwave instruments cover a range of 4 to 100 microns and measure the terrestrial or thermal radiation emitted by natural objects at or near the earth's surface; and instruments that measure visible light cover that portion of the spectrum from 0.4 to 0.7 microns.

We made a study to examine how much and in what way various instruments agree in their measurements of shortwave radiation, and to describe the seasonal effects of oak and pine canopies on shortwave, longwave, and net radiation. The study was conducted on the Lebanon Experimental Forest, near New Lisbon, New Jersey.

Methods

STUDY PLOTS

Radiation measurements were taken in three plots located within 300 yards of each other. One plot was an open area; one was a 100-x-100-foot area in a stand of mature oak, and one, of equal size, was located in a stand of mature pitch pine. The plots were almost level and had deep, well-drained, sandy soils. For sampling purposes the two forested plots were gridded into 10-foot squares whose intersections were marked with steel rods.

The open area was part of a clearing of about 5 acres. Radiation measurements were taken at an unshaded point over bare soil approximately 200 feet from the surrounding oak trees, which were about 40 feet tall.

The oak plot contained 115 chestnut oak, black oak, and white oak trees with an average diameter breast high of 4.1 inches and a basal area of 66 square feet. Dominants within the even-aged stand were 9 to 10 inches in diameter, about 40 feet tall, and 65 years old. Stocking was about 0.8 normal. Five or six small pines were removed from the stand before radiation measurements were begun. Summer canopy closure, as measured with a spherical densiometer, was about 65 percent, and winter closure about 15 percent. The forest floor was a patchy intermixture of about equal areas of bare soil, oak leaves, and moss.

The pine plot contained 32 pitch pines about 50 feet tall, 90 years old, and with an average diameter at breast height of 9.3 inches and a basal area of 70 square feet. Stocking was about 0.67 normal. Canopy closure was about 24 percent. Before measurements were begun a considerable oak understory, which had been killed by fire in 1963, was removed. The forest floor was a fairly uniform covering of pine needles, $\frac{1}{4}$ to $\frac{1}{2}$ inch deep, over $\frac{1}{2}$ to 1 inch of humus.

PERIOD OF RECORD

Radiation measurements were taken on 33 days during the period from April 17, 1964, to April 27, 1965. Each day measurements were begun at sunrise and taken hourly until sunset. During

16 days of measurement the oaks were in full leaf (the growing period), and during 13 days they were leafless (the dormant period).

From hourly estimates of cloud cover, 10 days were classified as uniformly clear (0 to 14 percent cloud cover), and 11 days were classified as uniformly cloudy (33 to 91 percent cloud cover). Four days had cloudy mornings and clear afternoons, and 2 days had the reverse condition. Six days were classified as irregularly cloudy. On 3 days (one cloudy and two clear) there was snow on the ground.

INSTRUMENTATION

Shortwave radiation was measured with four instruments, and longwave radiation was measured with one instrument. A daily record of shortwave radiation was also obtained from the Weather Bureau. Net shortwave, net longwave, net radiation (net all-wave radiation), and direct irradiation were calculated. Direct beam solar irradiation in langleys for each day of record were estimated from tables prepared by Fons *et al. (1960)* for a zero slope and atmospheric transmission of 0.9. Visible light was measured with one instrument. Cloud cover, in tenths of the sky covered, was estimated every hour.

Shortwave and longwave radiation measurements are expressed in langleys per day (a langley is 1 gram calorie of radiant energy per square centimeter). Visible light at noon is expressed in foot-candles. Units of measurement and the instruments used to measure radiant energy in the forest (including the instruments used in this study) have been described by Reifsnyder and Lull *(1965)*.

The instruments employed in this study were used as follows:

Shortwave Radiation

Eppley pyranometer.—Radiation in langleys per day for the 33 days of record, as recorded on the Eppley pyranometer, was obtained from the U. S. Weather Bureau Station at New Brunswick, N. J., 40 miles north of the Lebanon Experimental Forest.

Economical radiometer.—Three instruments were built by Irvin C. Reigner according to instructions given by Swan *et al. (1961)*

to measure incoming shortwave radiation in the open and beneath the canopies and to measure outgoing radiation from bare soil and forest floors. In the forest plots these instruments (and the pyranometers and atmometers) were read hourly and moved every 2 hours to randomly selected points on the grid.

Bellani spherical pyranometers.—These instruments were placed in insulated wooden containers to facilitate grid-sampling. The instrument on the pine plot was broken in November so that measurements for the last 12 days of record were not obtained. Pyranometers were calibrated at the open plot against daily langleys measured with the pyrheliograph.

Pyrheliograph.—The pyrheliograph was operated in the open plot only. Recorded langleys per minute were read either at 15-minute intervals, from a chart, or in multiples of 15 minutes during a period of little change, and were multiplied and added to get langleys per day.

Livingston atmometers.—One pair of black and white atmometers was employed in each plot from April 17 to November 2 when readings were discontinued because of freezing weather. The three black and three white atmometers were calibrated separately in the open with one black and one white designated as a standard. Differences in evaporation between black and white pairs measured in cubic centimeters and divided by daily langleys from the pyrheliograph for the calibration periods, give a calibration factor of 9.6 langleys per cubic centimeter.

Longwave Radiation

Economical radiometer.—Longwave radiation from economical radiometer readings was calculated according to procedures described by Swan *et al. (1961)*.

Net Radiation

Economical radiometer.—Net shortwave, net longwave, and net radiation values were computed according to procedures given by Swan *et al. (1961)*.

Visible Light

Brockway exposure meters, Model S, were used to measure visible light at 20 randomly selected points every hour in the forested plots, and at one point in the open every 30 seconds for 10 minutes each hour. Photocell readings were converted to foot-candles, according to the manufacturers' instructions, and then converted to langleys with the approximation that 7,000 foot-candles equal 1 langley per minute.

Results

SHORTWAVE RADIATION

Comparison of Instruments in Open Plot

Daily total shortwave radiation in langleys in the open for the 33 days of record was computed from measurements taken with the Eppley pyranometer (Ep), economical radiometer (Ec), Bellani pyranometer (B), pyrheliograph (Py), and the photocell (Ph). Simple correlation coefficient between daily values for the total record and for clear and cloudy days are given in table 1.

For the 33-day record the highest correlation was between the economical radiometer and the pyrheliograph, and the lowest was between the Bellani and Eppley pyranometers. Correlations of the pyrheliograph and the economical radiometer with the other three instruments on the plot were somewhat higher than correlations of the distantly located Eppley pyranometer with these instruments. In each of the correlations the coefficients were higher for clear days than for cloudy days.

Linear regressions for predicting daily radiation in langleys, with four instruments, and with the pyrheliograph used as the standard, are given in table 2 together with standard errors of estimate. For the total record and for clear and cloudy days the best estimates were made with the economical radiometer. Except for the Bellani pyranometer, standard errors were substantially smaller on clear days than on cloudy days. Standard errors in these predictions may be derived partly from the pyrheliograph record. In two recent comparisons with Kipp solarimeters, standard

Table 1.—*Correlations between daily total shortwave radiation as measured by five instruments*

Item[1]	Ep	Ec	Py	B	Ph
		TOTAL RECORD (33 days)			
Ep	—	0.935	0.945	0.851	0.936
Ec	0.935	—	.986	.927	.974
Py	.945	.986	—	.925	.981
B	.851	.927	.925	—	.904
Ph	.936	.974	.981	.904	—
		CLEAR DAYS (10)			
Ep	—	.994	.995	.976	.989
Ec	.994	—	.998	.973	.989
Py	.995	.998	—	.974	.994
B	.976	.973	.974	—	.962
Ph	.989	.989	.994	.962	—
		CLOUDY DAYS (11)			
Ep	—	.822	.810	.802	.867
Ec	.822	—	.978	.964	.978
Py	.810	.978	—	.954	.963
B	.802	.964	.954	—	.913
Ph	.867	.978	.963	.913	—

[1] Eppley pyranometer (Ep), economical radiometer (Ec), pyrheliograph (Py), Bellani pyranometer (B), and the photocell (Ph).

errors of pyrheliographs were found to be 19 and 21 langleys per day. The correlation coefficient in each case was 0.990.[1]

The relationships between daily values of the pyrheliograph ($\hat{Py}$) and direct-beam solar-irradiation estimates (X) for the 33-day record, gave a simple correlation coefficient of 0.856 and the regression equation:

$$\hat{Py} = 0.5505X + 20.8$$

The standard error of estimate was 82 langleys. Including percent of cloud cover, with an arc sin transformation (angle = arc sin $\sqrt{\text{percent}}$) gave the following equation:

$$\hat{Py} = 0.004993X\ (150 - \text{angle}) + 6.93$$

The correlation coefficient increased to 0.963, and the standard error of estimate was reduced to 43 langleys.

[1] Information provided by C. Anthony Federer, Watershed Management Research Project, Northeastern Forest Experiment Station, Durham, N. H.

Table 2.—*Regression equations and standard error of estimates for predictions of daily total radiation as measured with the pyrheliograph used as the standard*

Instrument	b-coefficient	a-constant (langleys)	Standard error of estimate (langleys)
TOTAL RECORD (33 days)			
Economical radiometer	0.8185	−2.68	27
Photocell	.8727	−27.50	31
Eppley pyranometer	.8482	−11.98	52
Bellani pyranometer	.8830	58.17	61
CLEAR DAYS (10)			
Economical radiometer	.8000	−.50	12
Photocell	.9418	−66.04	23
Eppley pyranometer	.8878	−25.78	20
Bellani pyranometer	.9538	44.32	46
CLOUDY DAYS (11)			
Economical radiometer	.8446	−8.25	29
Photocell	.7791	12.31	37
Eppley pyranometer	1.0472	−85.77	81
Bellani pyranometer	.8485	51.44	41

Correlation of the 18-day record from the atmometers with concurrent values from the pyrheliograph gave a correlation coefficient of 0.808. A regression for the prediction of daily pyrheliograph values ($\hat{Py}$) from atmometer values (X) gave the equation:

$$\hat{Py} = 0.6190X + 179.7$$

with a standard error of estimate of 68 langleys.

Mean incoming daily shortwave radiation from the pyrheliograph record for the growing season was 434 langleys and for the dormant season 287 langleys. Therefore, the standard error of estimate of 27 langleys from the most closely correlated instrument, the economical radiometer, was about 6 percent of the growing-season mean and 9 percent of the dormant-season mean. The standard error of the photocells, 31 langleys, indicated a close relationship between visible-light and shortwave measurements. Eppley pyranometer values from 40 miles away, and estimates of daily irradiation corrected for cloud cover, had about

the same magnitude of error, 52 and 43 langleys. The Bellani pyranometers and atmometers also had about the same degree of error, 61 and 68 langleys. These last two instruments were not considered useful because of operational difficulties, danger of breakage, and high threshold values.

Daily Shortwave Radiation Beneath the Canopies

Daily and seasonal amounts of incoming and outgoing shortwave radiation are indicated in figure 1. This figure brings out the pronounced seasonal variations in the incoming radiation, and the changing relationship between plot values with seasonal changes in the oak canopy. In sharp contrast are the comparatively small amounts and small variations in outgoing radiation; high values on January 19 and February 3 were due to reflection from snow.

During the 33 days, the oak plot received 53 percent of the shortwave radiation received in the open, and the pine plot received 63 percent as measured by the economical radiometer (table 3). The percent-of-open values principally reflect differences between the oak and pine plots in stocking and canopy closure during the growing season, and between deciduous and evergreen effects in the dormant season. More shortwave radiation penetrated the oak canopy in the dormant season than in the growing season despite a dormant-season reduction of about one-third in the available incoming amount. More shortwave radiation was reflected from the open plot than from the forested plots. For the total period there was little difference in the amounts reflected from the oak and pine plots.

On the 2 cloudiest days during the dormant season the oak plot received 77 and 79 percent of radiation in the open, and on the 2 clearest days 66 and 75 percent (table 4). Comparable values for the 2 cloudiest and 2 clearest days in the growing season were 44 and 46 percent and 50 and 23 percent. Greater proportions on cloudy days, due to the greater penetration of scattered radiation, have been reported by others *(Reifsnyder and Lull 1965)*.

In the pine plot, with lower canopy closure, differences in the

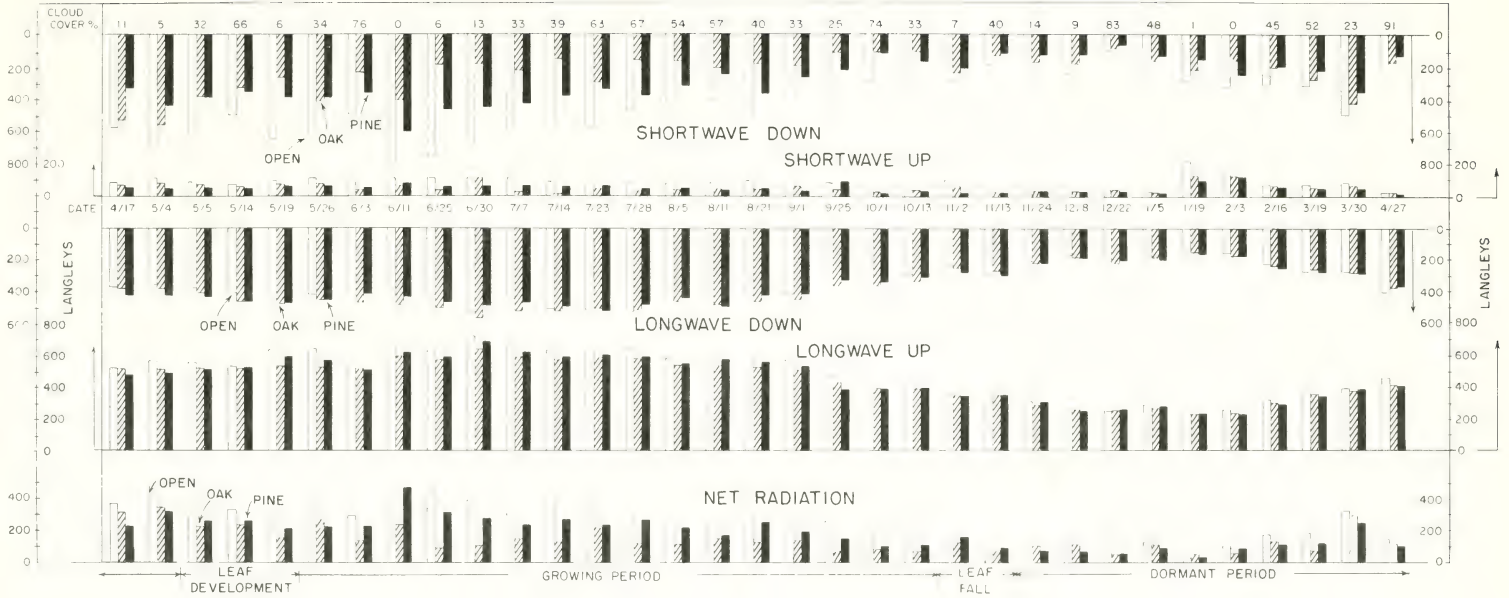

Figure 1.—Daily incoming and outgoing shortwave and longwave radiation and daily net radiation.

Table 3.—*Mean daily radiation*

Period	Number of days	In langleys			Percent of open	
		Open	Oak	Pine	Oak	Pine
		SHORTWAVE RADIATION				
Total:						
Incoming	33	448	237	284	53	63
Outgoing	33	81	49	45	—	—
Growing season:						
Incoming	16	525	205	341	39	65
Outgoing	16	85	40	49	—	—
Dormant season:						
Incoming	13	361	278	221	77	61
Outgoing	13	78	59	44	—	—
		VISIBLE LIGHT				
Total:	33	449	147	237	33	53
Growing season	16	528	102	287	19	54
Dormant season	13	360	197	186	55	52
		LONGWAVE RADIATION				
Total:						
Incoming	33	364	386	380	106	104
Outgoing	33	482	438	446	91	93
Growing season:						
Incoming	16	443	477	453	108	102
Outgoing	16	583	519	534	89	92
Dormant season:						
Incoming	13	269	275	289	102	107
Outgoing	13	361	341	337	94	93
		NET RADIATION				
Total:	33	244	133	177	55	73
Growing season	16	301	124	218	41	72
Dormant season	13	184	145	128	79	70

proportions recorded on cloudy and clear days were not as marked. On the 2 cloudy days during the dormant season 59 and 61 percent of the radiation in the open was received, and on 2 clear days 52 and 76 percent. During the growing season the respective values were 72 and 47 percent, and 76 and 60 percent.

The estimated transmission of solar radiation of the two forest plots in relation to stem density (the summation of diameters breast height per acre) taken from a relationship developed by Miller (1959), and actual transmission, were as follows:

Plot	*Stem density (in./acre)*	*Estimated transmission (%)*	*Actual transmission (%)*
Oak: growing period	2,252	38	39
Pine	1,302	60	63

Miller's relationship, developed from radiation measurements in pine stands, in this instance works well for oak in full canopy.

Estimates of transmission from crown closure measurements were not as good:

Plot	*Crown closure (%)*	*Estimated transmission (%)*	*Actual transmission (%)*
Oak: growing period	65	8	39
dormant period	15	63	77
Pine (a)	24	43	62
Pine (b)	24	58	62

The oak and pine (a) estimates were made from Miller's relationship *(1959),* and the pine (b), the best estimate, from a crown closure-percent transmission curve developed for jack pine *(Vézina and Péch 1964).* In the first three cases, transmission is more closely estimated by simple subtraction of crown-closure percent from 100. The poorness of these estimates corroborates Miller's conclusion that stem density is a better indicator of transmission than crown closure.

Table 4.—*Shortwave radiation on clear and cloudy days*

Period	Date	Percent	In langleys			Percent of open	
			Open	Oak	Pine	Oak	Pine
Growing season:							
Clear	6/11	0	803	399	607	50	76
	6/25	6	766	176	460	23	60
Cloudy	6/3	76	492	217	353	44	72
	10/1	74	241	112	113	46	47
Dormant season:							
Clear	1/19	1	290	212	150	73	52
	2/3	0	325	214	247	66	76
Cloudy	12/22	83	103	79	61	77	59
	4/27	91	202	159	123	79	61

Albedos

Mean albedos (outgoing shortwave radiation divided by incoming) and their standard deviations were calculated for the soil surface of the open plot and for the forest floors of the oak and pine plots for the 30 days of record (excepting the 3 days with snow cover), for 10 days of the dormant season when the oaks were leafless, and for 16 days of the growing season when hardwoods were in full leaf. The results are given in table 5, together with daily albedos for the 3 days of snow cover.

Albedos of the forest floor averaged 0.19 for the oak plot and 0.14 for the pine plot and were similar to canopy values that range from 0.15 to 0.20 for hardwoods and 0.10 to 0.15 for conifers *(Budyko 1956)*. Differences in albedos of the 30-day record among the three plots were highly significant ($F = 7.08$). There was little or no difference in albedos during the dormant and growing seasons in the open and pine plots. The forest floor of the oak plot reflected more shortwave radiation in the summer than in the winter, but the difference evaluated in a t-test proved non-significant ($p = 0.10$).

Smaller albedos of the deeper snow in the forested plots may

Table 5.—*Mean albedos and their standard deviations and albedos for days of snow cover*

Period	Plot					
	Open		Oak		Pine	
	Albedo	Standard deviation	Albedo	Standard deviation	Albedo	Standard deviation
30-day record	0.16	0.03	0.19	0.05	0.14	0.06
Growing season	.16	.03	.20	.04	.14	.07
Dormant season	.16	.03	.17	.04	.15	.05
Days with snow						
Date / *Depth (inches)*						
12/22 / 1	.25	—	.25	—	.32	—
1/19 / 7	.72	—	.59	—	.59	—
2/3 / 1	.54	—	.48	—	.53	—

have been due to stems or footprints in view of the radiometer and to the greater proportion of infrared radiation beneath the canopy.

VISIBLE LIGHT

The mean daily value of visible light measured with photocells and converted to langleys is given in table 3. Visible light was more greatly affected by canopies than was shortwave radiation since the foliage transmitted less of the visible light than the infrared. For instance, during the growing season the oak plot received 19 percent of the visible light received in the open, and the pine plot received 54 percent; comparable values for shortwave radiation were 39 and 65 percent (table 3). Dormant-season percents were 55 and 52 for visible light and 77 and 61 for shortwave radiation.

Photocells can provide a good estimate of shortwave radiation in the open, as noted earlier, but cannot be used to estimate it beneath the canopy.

Visible Light at Noon Beneath the Canopies

Visible light at noon beneath the canopies was measured to compare canopy effects on maximum values of visible light and to describe its area variation. Photocell readings, taken at 20 points in the forested plots at noon, were converted to foot-candles; and mean values and standard deviations were calculated for the 20 readings taken at 30-second intervals in the open area. Mean values by periods and for specific days are given in table 6.

For the 33-day record the oak plot received 37 percent of the light received in the open, and the pine plot received 52 percent.

Table 6.—*Visible light at noon*

Period	Number of days	In foot-candles			Percent of open	
		Open	Oak	Pine	Oak	Pine
Total	33	7,000	2,590	3,640	37	52
Growing season	16	7,840	1,610	4,130	21	53
Dormant season	13	6,090	3,640	3,080	60	51

Table 7.—*Visible light at noon on clear and cloudy days*

Period	Date	Percent	In foot-candles			Percent of open	
			Open	Oak	Pine	Oak	Pine
Growing season:							
Clear	6/11	0	9,945	2,955	5,270	30	53
	6/25	6	9,675	1,936	5,205	20	54
Cloudy	6/3	76	7,620	1,980	2,852	26	37
	10/1	74	6,285	1,136	3,232	18	51
Dormant season:							
Clear	1/19	1	7,200	3,098	3,772	43	52
	2/3	0	7,350	3,405	3,404	46	46
Cloudy	12/22	83	1,200	588	602	49	50
	4/27	91	1,470	1,062	870	72	59

The oak plot received somewhat more light than the pine plot in the dormant period; but in the growing period it received less than half of that received in the pine plot, and less than one-quarter of that in the open. In both seasons, the pine plot received about one-half of the light measured in the open. The differences in light measured at the open plot in the dormant and growing periods result from different positions of the sun and different degrees of cloudiness (mean daily cloudiness in the dormant season was 32 percent, and in the growing season 40 percent).

On clear and cloudy days during the growing season the oak plot received about one-sixth to one-third of the light received in the open and one-third to two-thirds of the light received in the pine plot. In the dormant season the oak plot received about one-half to three-fourths of the light received in the open and about the same amount of the light measured in the pine plot (table 7).

On clear days during the growing season all plots received about 1.5 times more light than on cloudy days. During the dormant season the multiple was increased to about 5.0.

Areal variation of noon radiation is indicated by the following coefficients of variation:

	Open	*Oak*	*Pine*
Total record	11	47	38
Growing season	14	85	33
Dormant season	9	30	46

During the growing season the greatest variation was found on the oak plot, and during the dormant season in the pine plot. Greater variation in the open plot during the growing season was probably due to greater cloudiness.

LONGWAVE RADIATION

Daily incoming and outgoing daytime longwave radiation of the three plots are given in figure 1. Mean values by seasons are given in table 3.

In both seasons incoming radiation from atmosphere and overhead foliage and branches is greater beneath the canopies than incoming radiation to the open from atmosphere alone. Differences in outgoing radiation stem from differences in surface-soil temperatures resulting from variation in shading.

Daily values shown in figure 1 point up the large seasonal difference in longwave radiation, the relatively small difference between plots (as compared with shortwave radiation), and the overall negative net values.

NET RADIATION

Daily Net Radiation

Daily net radiation from economical radiometers is given in figure 1. Mean values by seasons are given in table 3. Net radiation from the growing to the dormant season in the open and pine plots is reduced about one-third, but in the oak plot it is increased about one-third because of the differences in seasonal distribution of shortwave radiation noted above. Small differences in longwave radiation between plots suggest that net radiation differences can be attributed mainly to variation in shortwave distribution.

Net Radiation and Shortwave

About one-half to two-thirds of the shortwave radiation as measured with the economical radiometers appeared as net radiation. The net to shortwave ratios were as follows:

	Open	*Oak*	*Pine*
Growing season	0.57	0.60	0.64
Dormant season	.51	.51	.58

Maximum daily ratios for the open, oak, and pine plots were 0.70, 0.76, and 0.82 respectively. Minimum values of 0.07, 0.16, and 0.23 were for days of snow cover.

The relationships of net radiation to shortwave and to net shortwave radiation are given in table 8. The simple correlation coefficients indicate that from 89 to 94 percent of the variation in net radiation is attributable to variation in shortwave radiation, and from 92 to 96 percent to net shortwave radiation. Standard errors of estimate are about 10 to 20 percent of the mean net radiation value by seasons.

RADIATION BALANCE ON CLEAR DAYS AND CLOUDY DAYS

Seven days of record were selected to exemplify the radiation balance on clear days and cloudy days during the growing and dormant periods (table 9). Radiation values were from the economical radiometers.

Table 8.—*Relation of daily net radiation to daily shortwave and daily net shortwave radiation*

Plot	Independent variable	Correlation coefficient	Regression statistics		
			b-coefficient	a-constant	Standard error of estimate
				Langleys	*Langleys*
Open	Shortwave	0.942	0.5364	11.3	34
	Net shortwave	.959	.6579	6.4	28
Oak	Shortwave	.948	.6325	−12.3	25
	Net shortwave	.982	.7549	−5.8	15
Pine	Shortwave	.971	.7109	−21.9	22
	Net shortwave	.976	.8159	−18.5	20

Table 9.—*Radiation balance on clear days and cloudy days, in langleys*

Item		Clear days			Cloudy days			
		Example 1 (no leaves)		Example 2 (full leaf)	Example 3 (no leaves)		Example 4 (full leaf)	
Date		12/8	5/4	6/25	4/27	3/9	6/3	8/5
Cloudiness (%)		9	5	6	91	52	76	54
Direct beam		230	779	895	743	490	878	795
Radiation	*Site*							
Shortwave	Open	237	723	766	202	318	492	432
	Oak	177	560	176	159	281	217	157
	Pine	117	433	460	123	208	353	310
Shortwave	Open	45	110	121	17	58	81	61
	Oak	32	84	38	17	49	47	31
	Pine	20	49	154	6	39	53	38
Net	Open	192	613	645	185	260	411	371
	Oak	145	476	138	142	232	170	126
	Pine	97	384	406	117	169	300	272
Longwave	Open	182	365	432	410	283	403	461
	Oak	193	389	506	374	274	469	484
	Pine	202	423	479	380	280	426	471
Longwave	Open	259	561	638	453	360	532	520
	Oak	248	517	567	405	344	508	520
	Pine	248	491	580	406	336	502	538
Net	Open	−77	−196	−206	−43	−77	−129	−125
	Oak	−55	−128	−61	−31	−70	−39	−36
	Pine	−46	−68	−101	−26	−56	−76	−67
Net	Open	115	417	439	142	183	282	246
	Oak	90	348	77	111	162	131	90
	Pine	51	316	305	91	113	224	205

Example 1.
Clear Days, No Oak Leaves,
Winter and Spring
(December 8 and May 4)

Relative magnitudes of shortwave and longwave radiation among the three sites are similar for these 2 days despite the large difference in shortwave radiation received.

For both days the greatest amounts of incoming, outgoing, and net shortwave radiation were measured in the open, the least in the pine plot, and intermediate values in the hardwood area. The greatest amounts of incoming longwave radiation, and the smallest amounts of outgoing were measured under pine. Negative net thermal values increased markedly for open and hardwood sites from the winter to the spring dates; whereas there was a smaller change in net thermal radiation for the pine site.

Net radiation diminished from the open to the hardwood to the pine and was governed mainly by the trend of incoming shortwave radiation.

Example 2.
Clear Day, Full Leaf
(June 25)

A comparison of this radiation balance with that of May 4 points up the canopy change in the oak plot. Incoming, outgoing, and net shortwave radiations were sharply reduced; incoming longwave radiation for the oak plot was greater than that for the open and pine plots, and outgoing radiation was less. Net radiation for the oak plot was but a fifth of its value in early May, but there was little change in the open and pine plots.

Example 3.
Cloudy and Partly Cloudy Days,
No Oak Leaves
(April 27 and March 9)

The 91-percent cloudiness of April 27 reduced shortwave and net radiation by one-fourth to one-third of that of the clear day May 4; reduction in reflected shortwave radiation was even greater. Incoming longwave radiation, for the first time in these

examples, was greatest in the open, and there was little difference between incoming and outgoing thermal radiation in the forested plots. Net radiation at the three sites was affected mainly by the distribution of shortwave radiation.

On March 9, with a cloudiness of 52 percent, incoming solar radiation was somewhat greater than on April 27 even though direct beam was much less; longwave values were relatively uniform, and the net value again mainly suggests differences in incoming shortwave radiation.

Example 4. Cloudy and Partly Cloudy Days, Full Leaf (June 3 and August 5)

These 2 days as compared with the clear day of June 25 show a reduced shortwave radiation but a reduction disproportionately less in the oak plot. (The high value of 217 langleys for June 3 is presumably a sampling variation.) With longwave values fairly uniform, net values for the open and pine plots were substantially less than comparable values on June 25, and oak values were greater.

Summary

Within the limited scope of this study certain results were evident. In regard to instrumentation:

- Economical radiometers were not difficult to construct and gave apparently good measurement of incoming and outgoing shortwave and longwave radiation.

- The Bellani pyranometers used in this study were not satisfactory because of their high threshold values and standard errors of estimate. However, other investigators have found various models useful *(MacHattie, 1961; Vézina and Péch, 1964).*

- Livingston atmometers were relatively insensitive, very likely to damage, and time-consuming to operate; and they could

not be used in freezing weather. For shortwave estimation they were not satisfactory.

- Photocells, despite their limitations in the spectrum measured, correlated well with shortwave measurements in the open but because of differential transmission of visible light could not be used to estimate shortwave radiation beneath the canopy.

- The economical radiometer and the photocell were equally effective in measuring shortwave radiation in the open. However, standard errors of estimate of 27 and 30 langleys with these two instruments may preclude their use in studies requiring precise comparisons.

Distribution of radiation in the forest plots was as follows:

- The oak plot received 39 percent of incoming shortwave radiation during the growing season, and the pine plot received 65 percent. Comparable dormant-season values were 77 and 61 percent.

- More shortwave radiation penetrated the oak canopy in the dormant season than in the growing season despite a seasonal reduction of about one-third in the incoming amount in the dormant season.

- The oak plot received a greater proportion of the incoming shortwave radiation on cloudy days, and the pine plot received a greater proportion on clear days.

- The percent of shortwave radiation received in the forest plots was accurately estimated from a stem density-radiation relationship developed by Miller *(1959)*.

- Albedos of the forest floor averaged 0.19 for oak and 0.14 for pine.

- During the growing season the oak plot received 19 percent of the visible measured light at the open plot, and the pine plot received 54 percent; comparable values for the dormant season were 55 and 52 percent.

- At noon during the growing season, visible light throughout the oak plot was about six times more variable, and throughout the pine plot about twice as variable as in the open. In the dormant season, variation in the oak plot was three times that of the open, and in the pine plot five times that of the open.
- Incoming longwave radiation from the sky and canopy was slightly greater in the forested plots than in the open, and outgoing radiation was greater in the open than in the forest.
- Net radiation was greatest in the open plot; during the growing season it was smallest in the oak plot and during the dormant season, in the pine plot.
- From 89 to 94 percent of the variation in daily net radiation was attributable to variation in daily shortwave radiation.

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CLEARCUTTING

in Northern Hardwoods: Results after 30 Years

U. S. FOREST SERVICE RESEARCH PAPER NE-85
1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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CLEARCUTTING in Northern Hardwoods: Results after 30 Years

■

Common and Scientific Names of Species Mentioned in this Paper

Paper birch	*Betula papyrifera* Marsh.
Yellow birch	*Betula alleghaniensis* Britton
Sugar maple	*Acer saccharum* Marsh.
Red maple	*Acer rubrum* L.
White ash	*Fraxinus americana* L.
Beech	*Fagus grandifolia* Ehrh.
Aspen	*Populus grandidentata* Michx. or *Populus tremuloides* Michx.
Pin cherry	*Prunus pensylvanica* L. or *Prunus virginiana* L.
Striped maple	*Acer pensylvanicum* L.
Raspberry, blackberry	*Rubus* sp.
Hemlock	*Tsuga canadensis* L.

A Case History

THE TREND toward even-aged management of hardwoods has developed more slowly in the northern hardwood type than in most other types. This is partly because several of the northern hardwood species are shade-tolerant and can be managed successfully on an uneven-aged basis. But even in this type there is an increasing awareness that timber returns may be greatest under some form of even-aged management that will maintain high proportions of the valuable intolerant and intermediate species.[1]

Numerous studies have shown that small patch or strip clearcuttings provide optimum conditions for establishment of paper and yellow birch—two of the most valuable northern hardwoods *(4, 5, 6, 7, 8, 11)*. The smaller openings seem especially desirable for yellow birch *(4, 6, 11)*. However, there are little data to show that the abudance of seedlings established in these small openings is needed. Some foresters feel that the smaller numbers of seedlings established in large clearcuttings are adequate to provide a fully stocked stand.

Unfortunately there have been few attempts to apply complete

[1] The values attached to resources other than timber also are important in the choice of management systems. The northern hardwood forests of New England have always had high recreation values; clearcuttings associated with even-aged management will not be appropriate in many areas where recreation is the primary resource.

clearcutting to northern hardwood forests. One notable exception is a 22-acre tract on the Bartlett Experimental Forest in New Hampshire. Jensen *(2)* has reported on the regeneration present 5 years after clearcutting on that tract. The regeneration there has now developed into a 30-year-old stand; and this stand provides a unique opportunity to examine the case history of a northern hardwood stand resulting from complete clearcutting.

Area Studied

The clearcutting took place in an old-growth northern hardwood stand composed primarily of beech (61 percent), yellow birch (15 percent), and sugar maple (15 percent).[2] There were also small amounts of red maple, white ash, and paper birch in the overstory. Basal area of the stand averaged 122 square feet per acre in trees 4.6 inches d.b.h. and larger. The advanced regeneration present was primarily sugar maple, beech, and striped maple (table 1).

The stand was located on a lower slope of 20 to 25 percent, at an elevation of about 1,100 feet. The aspect is northly. The soil is a Hermon stony, sandy loam—a well-drained podzol derived mainly from granite and granitic gneiss glacial till. The mor humus depth averaged about 3 inches over the study area. Site index for paper birch is estimated to be 70[3] on this area.

Clearcuttings were made on three plots of 5 acres each, plus an additional area of 7 acres. Cutting was done during the winters of 1933, 1934, and 1935, but much of the material was removed during the snow-free season. An average of 60 cords of split wood per acre was removed. All hardwoods 1.6 inches d.b.h. and larger and all conifers 4.6 inches d.b.h. and larger were cut except for a few of the larger white ash, which were left as seed trees. Advanced reproduction on about half of the area was mowed, but this had little effect on the reproduction *(3)*. All subsequent measurements were limited to the 15-acre area contained within the three plots.

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[2] Percentages based on basal area in trees 4.6 inches d.b.h. and larger.

[3] Site index based on height of dominant and codominant paper birch at 25 years of age, using Curtis and Post curves (*1*) with a base age of 50 years.

Table 1. — *Reproduction and stand development*

Species	Advance reproduction		At 5 years		At 25 years		At 30 years [1]	
	Trees 1 foot high to 1.5 inches d.b.h.		Trees 1 foot high or higher		Trees 0.6 inch d.b.h. or larger		Trees 0.6 inch d.b.h. or larger	
	Stems per acre	*Percent*	*Stems per acre*	*Percent*	*Stems per acre*	*Percent*	*Stems per acre*	*Percent*
				TOLERANT				
Beech	3,321	26	6,485	19	1,032	25	786	30
Sugar maple	7,245	56	9,745	29	1,041	26	776	29
Striped maple	2,085	16	1,515	4	127	3	63	2
Conifers	82	1	30	(*)	58	1	49	2
				INTERMEDIATE				
Yellow birch	177	1	2,719	8	474	12	325	12
White ash	29	(*)	279	1	93	2	64	2
Red maple	—	—	278	1	176	4	112	4
				INTOLERANT				
Paper birch	—	—	3,296	10	401	10	294	11
Aspen	7	(*)	874	3	54	1	47	2
Pin cherry	—	—	8,204	25	636	16	168	6
All species	12,946	100	33,425	100	4,088	100	2,684	100

* Less than 0.5 percent.

[1] Because of slight differences in species composition among the 5 control plots used at age 30 and the entire 20 plots used at age 25, the figures presented here for 30 years have been adjusted to reflect the composition of all 20 plots.

Study Methods

The advanced regeneration present before cutting, and regeneration present 5 years after cutting were tallied by species and height classes on milacre sample plots. These data have been published previously *(2)*, but they are presented here in condensed form for comparison with the present stand. In 1959 and again in 1964, 100 percent tallies were taken of all trees present on twenty ¼-acre plots regularly spaced within the three original 5-acre plots. At the time of the 1959 tally, approximately 100 potential crop trees were selected on each ¼-acre plot; these trees were permanently marked and numbered, and detailed measurements were taken on a sample of 382 of them. The measurements include: diameter at breast height and at the top of the first log; merchantable height; total height; crown size, crown class, and crown vigor; clear length of bole; number and location of branches, epicormic branches, and bole defects; bole quality class; and others. These measurements permit detailed evaluation of individual tree development.

The potential crop trees were selected on the basis of: species (paper birch, yellow birch, white ash, and sugar maple were given preference, but red maple and beech were accepted where necessary); origin (seedlings were given preference over sprouts); crown class and size (large dominant and codominant trees were given preference, but some intermediates were accepted where necessary); and bole condition (clean, straight boles with a minimum of defects were given preference).

A sequential multiple comparison test as outlined by Snedecor *(9)* was used to test differences among species in the various crop-tree attributes.

A thinning study was established on the twenty ¼-acre plots in 1959, when the stand was 25 years old. Data shown in this paper for 1964 (30 years after cutting) are therefore based only on five plots used as controls in the thinning study. Data on stand structure and individual tree characteristics are presented from the 1959 data to permit averaging of all sample trees and to avoid inclusion of treatment effects.

Stand Development After Clearcutting

Advanced reproduction before cutting was composed almost entirely of tolerant species (table 1). Immediately after cutting, raspberries, blackberries, and other herbaceous species dominated the area; along with stump sprouts, root suckers, and weed species like pin cherry, they appeared to offer little promise for the future. However, within a few years seedlings of more valuable species began to emerge from the brush. At 5 years of age, aspen, pin cherry, and paper birch were dominant, and large numbers of more tolerant species had become apparent. Pin cherry was the most prominent species; it occurred in large numbers and was taller than all other species except aspen. Although aspen was not numerous over the entire area, it was important in some spots. Aspen occurred in clumps — originating primarily from root suckers—where it grew rapidly and sometimes excluded all other vegetation.

The short-lived pin cherry began to drop out of the stand after about 15 years. Although some pin cherry trees are still surviving at age 30, mortality is now high; nearly 75 percent of the pin cherry present in 1959 died before 1964. At 30 years of age aspen, paper birch, and white ash are the dominant species; and red maple, yellow birch, sugar maple, and beech are present as codominants or lower crown classes.

Table 2.—*Stand characteristics at 25 years of age*

Tolerance group	Number of trees		Basal area		Average d.b.h
	Number	*Percent*	*Square feet per acre*	*Percent*	*Inches*
Tolerants	2,257	55	25.4	26	1.3
Intermediates	743	18	17.9	18	1.8
Intolerants	1,091	27	55.9	56	2.7
Total	4,091	100	99.2	100	1.8

Intolerant and intermediate species have dominated the new stand from the start. They are the larger trees; they occupy much of the main crown canopy; and they represented 74 percent of the basal area at 25 years of age (table 2). However, in spite of their dominance, intolerant and intermediate species are not as numerous as tolerant species. Five years after cutting, four tolerant species comprised over half of the total number of stems. This proportion has increased gradually as the stand matured so that tolerant species account for 63 percent of the stems at 30 years of age (table 1).

Although this is an even-aged stand, it should be apparent from the discussion above that it is much more complex than the typical pure even-aged stand. The various species have markedly different growth rates, tolerances to shade and competition, and maturity ages. The crown canopy is not one narrow level but is nearly continuous from about 10 feet to 50 feet or more above ground. The slower growing tolerant species are often entirely beneath the main canopy of less-tolerant species. The diameter distribution of the stand has already assumed the inverse-J curve typical of uneven-aged stands (fig. 1).

If left to mature naturally, this stand will become increasingly similar to an uneven-aged stand. The short-lived pin cherry is already drying out; aspen can be expected to follow between 40 and 60 years of age; and paper birch will likewise mature by the time the stand reaches the 80-year mark. Red maple and white ash should survive past 100 years, but eventually they too will mature and the stand will then be dominated by the original, long-lived climax species—beech and sugar maple with small amounts of yellow birch. Any cutting in the stand to remove merchantable trees will hasten this process *(10)*.

The present stand is dense, and competition is severe. In 1959 there were over 4,000 stems 0.5 inches d.b.h. or larger per acre, and these stems represented 99 square feet of basal area. Mortality over the 5-year period 1959 to 1964 amounted to 35 percent of the number of stems. In spite of the high mortality, net growth during that 5-year period amounted to 2.2 square feet of basal area per acre per year, so that the present stand contains 110

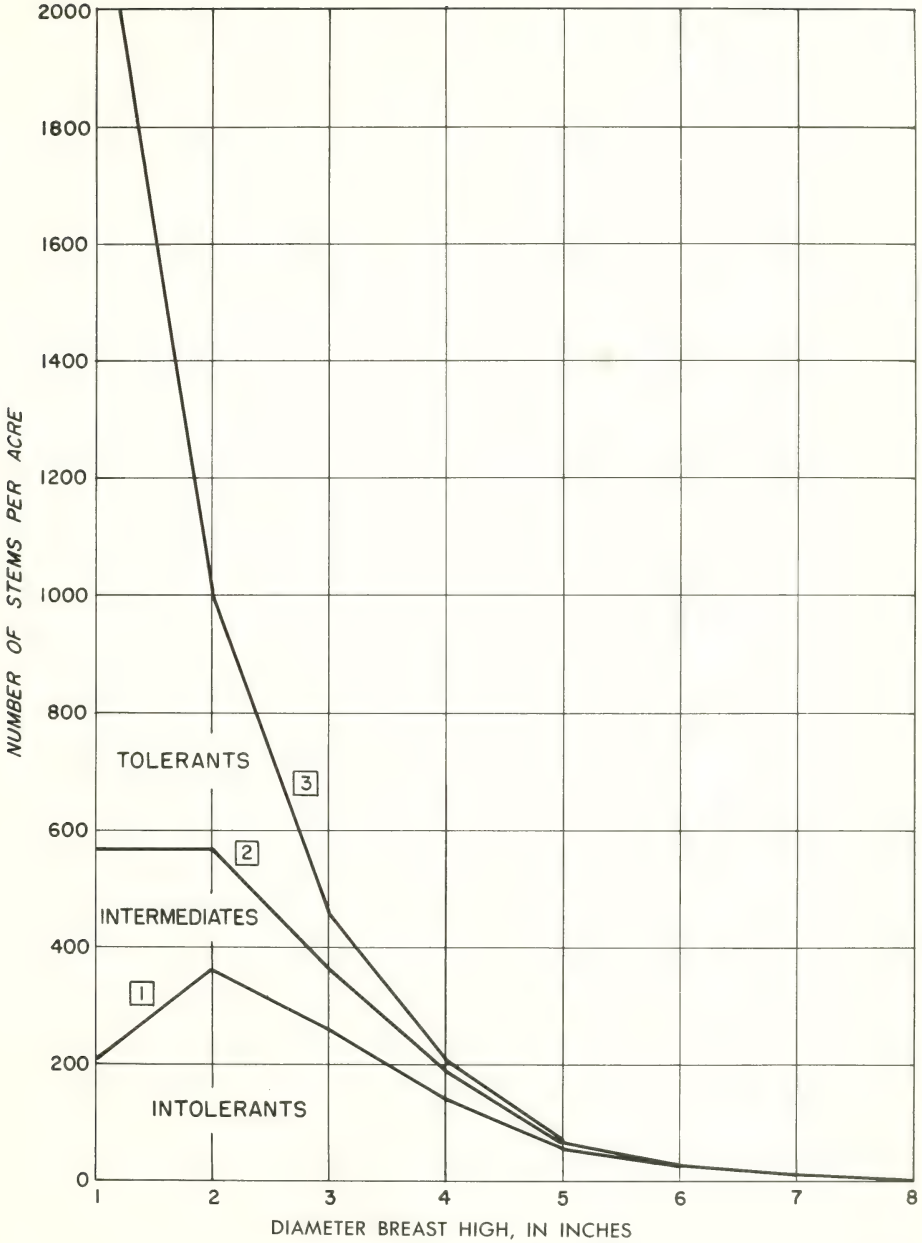

Figure 1.—Stand structure at 25 years of age. The curves are cumulative. That is, curve 1 represents intolerants only, curve 2 represents intolerants plus intermediates, and curve 3 represents all trees.

square feet per acre.[4] Growth on trees surviving the 5-year period was better than 4 square feet of basal area per acre per year. However, this growth is being spread over a large number of stems.

Characteristics of 25-Year-Old Trees

At 25 years of age, there was a sufficient number of desirable trees to permit selection of about 385 potential crop trees per acre. These trees represented 10 percent of the total number of stems and 30 percent of the basal area. About half of the potential crop trees were paper birch; the remainder were longer-lived species. A listing of potential crop tree characteristics is presented in table 3.

Based on the multiple comparison tests, the several species may be placed into groups representing similar qualities or sizes. Differences between the groups in the following discussion were statistically significant at the 0.05 level.

Paper birch had the largest average d.b.h. of all crop-tree species; white ash was second; yellow birch and red maple were third; and sugar maple and beech were fourth. Over the 25-year period, paper birch averaged 0.18 inches diameter growth per year, and sugar maple averaged 0.10 inches per year.

Paper birch and white ash were taller as a group than the other species. Red maple, yellow birch, and sugar maple were taller than beech. Paper birch averaged 1.7 feet of height growth per year as opposed to 1.3 feet per year for beech.

Crown size was expressed in four different ways. Differences among species in live crown length were not significant. But paper birch, white ash, and red maple had significantly larger crown areas and crown volumes than yellow birch, sugar maple, and beech. Crown ratio appears to be a poor measure of crown size: yellow birch and beech had larger crown ratios than the other four species, even though actual crown length was no

[4] For trees 4.6 inches d.b.h. or larger, basal area was 24 square feet per acre in 1959 and 52 square feet per acre in 1964.

Table 3.—*Characteristics of potential crop trees at 25 years of age*

Characteristic	Paper birch	White ash	Red maple	Yellow birch	Sugar maple	Beech	All crop trees
Trees per acre ..... number..	169	31	21	67	73	24	385
Diameter at breast height ..... inches..	4.4	3.9	3.5	3.2	2.8	2.7	3.7
Total height ..... feet..	43	42	37	36	34	32	37*
Crown length ..... feet..	22	21	20	21	19	18	20*
Crown ratio (length/total height) ..... ratio..	.50	.50	.52	.57	.55	.58	.54*
Crown area projection ..... square feet..	60	52	52	40	36	37	46*
Crown volume (area x length) ..... cubic feet..	1,481	1,227	1,142	867	742	714	1,019*
Trees in dominant crown class ..... percent..	33	20	9	0	0	2	10*
Trees in dominant and codominant crown class ... percent..	95	86	93	74	58	43	74*
Height to first branch ..... feet..	16	10	9	12	11	10	12*
Height to first live branch ..... feet..	21	21	17	15	15	14	17*
Branches on first log ..... number..	0.2	0.3	0.8	2.0	2.0	3.5	1.5*
Epicormic branches on first log ..... number..	0.0	0.0	0.4	2.5	2.8	4.6	1.8*
Trees with epicormic branches on first log ..... percent..	0	0	5	41	43	62	27*
Grade 1 trees [1] ..... percent..	38	30	14	10	5	5	17*
Grade 1 or 2 trees [1] ..... percent..	66	46	32	29	32	13	37*
Average taper in 1964 (d.b.h./diameter at 17 feet) ..... ratio..	.81	.75	.80	.76	.79	.72	.77*
Current growth, 1959 to 1964—controls only							
D.b.h. increment per year ..... inches..	.14	.16	.12	.09	.06	.07	.11
Height increment per year ..... feet..	1.8	1.9	2.0	1.8	1.7	1.4	1.7*

* Based on equal numbers of each species—not actual distribution.

[1] See text for description of bole grades.

greater and crown area and crown volume were smaller than the other species.

Crown class is closely related to species, stem size, and crown size. Most of the paper birch, red maple, and white ash crop trees were dominant or codominant. About one-fourth of the yellow birch and one-half of the sugar maple and beech were intermediate or suppressed.

Bole quality may be expressed in many different ways. Paper birch and white ash had longer boles clear of live branches than the other species. It is interesting to note that the butt logs are nearly clear of branches by the time the stand reaches 25 years of age, or a diameter of 3.5 to 4.0 inches. However, epicormic branches are common, even in this dense stand, on yellow birch, sugar maple, and beech. About half of the trees of these species have epicormic branches. However, not a single epicormic branch was found on either paper birch or white ash. About 10 percent of the potential crop trees had forks below 25 feet, regardless of species.

An arbitrary grading system was used to rate the quality of the first log. Grade 1 permitted no live branches or epicormic branches, and only slight lean, crook, or sweep. Grade 2 permitted one live branch, up to five epicormic branches, and moderate crook and sweep if located so that a 12-foot log could still be obtained. Trees with more branches or epicormic branches or more severe defects were placed in grades 3 or 4.

On this basis, the larger and faster growing paper birch and white ash were of higher quality than the other species. Only 37 percent of the crop trees qualified for grade 1 or 2, indicating that branches and minor defects are common in this age class. However, only grade 4 trees have defects that appear serious enough at this time to prevent them from developing into high-quality sawlogs, and 95 percent of the potential crop trees qualified for grade 3 or better.

A comparison of current growth rates of the crop trees with average rates over the first 25 years reveal some important trends. Height growth continues to be good: the crop trees have, in fact, grown more rapidly in height during the last 5 years than they

did the first 25 years. But increment of bole diameter has decreased over the last 5-year period. This may be indicative of the high stand density and competition.

Natural pruning is proceeding rapidly—at the rate of nearly 1.5 feet per year. Although this is desirable for stem quality, it indicates that the crown length is not increasing as the trees get larger. Proportionately shorter crown lengths may well be responsible for the reduction in bole growth that is already showing up.

Discussion

This case history demonstrates that vigorous new stands containing a high proportion of valuable species can be obtained by complete clearcutting in northern hardwoods (fig. 2). It does not suggest that such stands will always be obtained.

Some of the conditions at the time of this particular cutting are not very likely to be duplicated. Present-day markets will not permit utilization of small material such as occurred here. The absence of slash, the complete absence of residual trees, and the soil disturbance resulting from the removal of 60 cords per acre must have had a beneficial effect on the reproduction.

The cutting itself may not be entirely representative of large clearcuttings since it was spread over 3 years, and each year's cutting involved only about 7 acres. Furthermore, moisture conditions are favorable on this moderately steep north-facing slope. And although paper birch has become established in large numbers throughout the clearcut area, yellow birch of crop-tree quality is not so abundant nor so evenly distributed.

In some situations, smaller clearcuttings such as narow strips may be required to obtain the desired stocking, particularly where yellow birch is the primary species.[5] But in spite of these qualifications, clearcutting promises to be a practical and highly successful cutting method, once the conditions under which it will be successful are adequately defined.

In this study, the stand resulting from a complete clearcutting

[5] There are numerous second-growth stands in the northern hardwood area that resulted from commercial clearcuttings about 1880 to 1910. Some of these stands are poorly stocked with valuable species, and they offer much less promise than this study example.

Figure 2.—A vigorous 25-year-old northern hardwood stand resulting from clearcutting.

has clearly satisfied the original objective—to obtain a high proportion of the valuable intolerant and intermediate species. It contains the stocking, the spatial distribution, and the growth rate required to produce high-quality hardwoods.

This complex stand offers both problems and opportunities for timber management. There are enough potential crop trees of promising quality to permit several management alternatives. It would be entirely possible to manage the stand purely for the fast-growing, short-lived paper birch, using a short rotation and attempting to regenerate the stand when the paper birch is cut. There are 169 well-distributed paper birch crop trees per acre—

enough to provide a well-stocked pure paper birch stand at maturity.

Similarly, it would seem possible to manage for a double harvest, first of paper birch and later of the longer-lived yellow birch, sugar maple, and white ash. This would require judicious thinning to bring both groups along concurrently in the early stages. A third alternative would be to utilize the less tolerant species as they mature, but to purposely encourage the uneven-aged development of the stand for management of tolerant species through individual tree selection cuttings.

Regardless of the alternative selected, early thinnings or weedings appear to be needed if the stand is to achieve maximum growth and quality. These treatments would concentrate growth on a small number of selected stems with high potential value, reducing the rotation length and increasing the value of the material harvested.

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A Comparison of Four
SURVEY TECHNIQUES
Used in Outdoor Recreation Research

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U. S. FOREST SERVICE RESEARCH PAPER NE-86
1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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A Comparison of Four SURVEY TECHNIQUES Used in Outdoor Recreation Research

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WHAT KIND OF SURVEY?

BECAUSE of the great and growing interest in outdoor recreation, many studies are being made by private and public agencies that need information for planning use of land and facilities for recreational purposes.

In these studies much attention is being given to the people who use recreational facilities—who they are; where they come from; what they like; what they want; how much they are willing to spend. Many types of surveys are being used in studying these people.

The main question in planning a survey of this sort is: What survey technique can be used that will provide the most reliable and valid results at the least cost?

To get an answer that we could use in our recreation research program, we made a study of four different survey techniques—a personal interview, a handout questionnaire, an immediate mail questionnaire, and a delayed mail questionnaire. Results show that the delayed mail survey, conducted 3 months after the camping experience, gets the best results at the least cost.

Our study is described here for the benefit of other research workers in outdoor recreation.

GENERAL STUDY DESIGN

To begin with, we assumed that the personal-interview type of survey provides the most realistic replies to the questions asked. But the personal interview is the most expensive type of survey. So the purpose of our study was to determine whether a less expensive survey technique would adequately reproduce the result of a personal-interview survey.

The percentage of respondents who answered individual questions in the personal-interview survey was compared with the percentage of respondents who answered the same questions in a handout survey and two different mailed surveys. Also, the per-

centage response from the sampling frame for each survey technique was compared. A sampling frame is the total number of people selected for sampling.

The study was designed to detect differences—between the personal-interview results and results from each of the other survey techniques—that might significantly affect recreation management decisions. Before the study we asked recreation managers and planners throughout the Northeast: How large a percentage difference would there need to be between personal-interview response (the control) and nonpersonal-interview response to a question before you would use the more expensive personal-interview method to survey recreationists? Generally, with the type of questions used in this study, most managers suggested that response differences of about 8 to 10 percent or greater between the control and any of the other survey methods would necessitate use of the personal-interview technique.

Subject areas in the questionnaire, which was used for all four survey techniques, included: sociological characteristics of campers, purposes for camping, camping expenditure and investment patterns, income, and attitudes about various campground environmental conditions and administrative procedures.

Because of the subject matter investigated, study results are applicable mostly in future recreation-management surveys. However, analytical procedures—described in somewhat more detail than normally would be done if this paper were directed only at resource managers—may be a useful reference for recreation researchers.

EXPERIMENTAL DESIGN

Survey Techniques

The four survey techniques compared were: personal interview, handout, immediate mail, and delayed mail. The same questionnaire was used for all four surveys (appendix).

These techniques were applied at two New York State campgrounds—Fish Creek and Hearthstone Point—during the 3 summer months in 1964.

The questionnaire, which contained 17 questions, was printed

on light green paper and was folded into a brochure that was 8½ by 3 inches. To stimulate interest in the survey, a sketch of a woodland area was used as background material on the cover page.

Response patterns to the personal-interview technique were assumed to be the most valid measurements attainable of camper characteristics and opinions, and thus the personal-interview results served as the standard (or control) for evaluating results of the other three survey techniques. Although it is not always certain that this assumption is valid, personal-interview data generally are accepted as the most accurate measure of response patterns. With the personal-interview technique, non-response was negligible in the initial sample.

The handout survey was directed from the camper registration booth at the entrance to each park. As camping parties registered, certain ones received a questionnaire. They were requested to answer it and return it to the booth as they left the park after completing their visit.

In the immediate mail survey, questionnaires were mailed to selected camping parties immediately after they had completed their visit to the park.

In the delayed mail survey, questionnaires were mailed to sampled camping parties 3 months after they visited the park. A 3-month waiting period seemed sufficient for examining the effect of a time interval on respondent recall.

A cover letter and a postage-paid self-addressed business-reply envelope were included with all mailed questionnaires, including second, third, and fourth mailings to nonrespondents in the handout and mail surveys.

Sampling Procedure

Sampling was carried on throughout the summer. As each camping party entered a park, one of the four sampling techniques was assigned to it:

1. Personal interview.
2. Handout survey.
3. Immediately mailed questionnaire.
4. Delayed mail questionnaire.

The survey techniques were assigned in sequence as camping parties arrived: 1,2,3,4,1,2,3,4,1,2,3,4, and so on. Each new day the sampling sequence was taken up where it had been left off the day before.

Furthermore, each day all parties selected were assigned systematically to one of two replications. In this way a replication number (1 or 2) was permanently assigned to each camping party throughout the experiment, regardless of whether they responded to the initial survey, the follow-up procedures, or did not answer at all. The replicating procedure resulted in two complete and independent sets of data throughout each of the three experimental factors—the parks, months, and techniques—and this permitted testing the significance of interactions (to be discussed later in detail) among these factors.

The sampling pattern resulted in unequal numbers of observations among parks, months, survey procedures, and replications. No effort was made to randomly delete from or add to a particular sample in order to have exactly the same number of respondents throughout all categories in the experimental design.

It was necessary to record, from a park's registration file, the names and addresses of those parties selected for the handout and mailed surveys. Each party's name was assigned a number that corresponded to a coded number on the questionnaire they received. This procedure permitted identification of nonrespondents for use in additional waves.

Sample Size

The study was designed to detect differences between survey techniques that were important to management. For example, suppose *all* camping parties throughout the summer at the two parks had been personally interviewed, and for a given park-month category, 50 percent of the respondents answered a particular item within a question. Within the same park-month category in our experiment, we wanted a sufficient sample of respondents for each survey technique so that, 95 times out of 100, our sample percentage result (p) would be within $\pm$ 9 percentage points of the true value (P), when P $=$ 50 percent. The calculated sample size needed to meet our requirements was

125 respondents (Walker and Lev 1953) within each of the 24 technique-month-park categories. However, in the final results, sample sizes varied from 73 to 223, or about an average of 156 respondents, for any one technique-month-park category (table 1).

Variations in sample sizes were due to changes in campground use-intensity patterns, fluctuations in camper length-of-stay patterns, and unavoidable revisions in the sampling pattern. We did not have enough time and/or interviewers, especially during July and August, to interview all camping parties selected for personal interviews, and at the same time to maintain adequate sampling procedures at the campground registration booth for the handout and mailed surveys. Thus more respondents usually were included in the nonpersonal interview techniques (table 1).

Altogether, there were 48 cells in the study design: 4 techniques $\times$ 3 months $\times$ 2 parks $\times$ 2 replications $=$ 48 cells. Final sample sizes within the various cells varied from 36 to 120 (table 1). Usually, any sample size of less than 50 or 60 re-

Table 1.—*Number of questionnaires partially or totally completed within each survey technique, month, park, and replication*

Park	Replication	Survey technique			
		Personal interview	Handout	Immediately mailed	Delayed mail
		JUNE			
Fish Creek	1	50	52	53	49
	2	51	48	49	42
Hearthstone	1	37	54	47	45
	2	36	52	50	45
		JULY			
Fish Creek	1	66	101	89	96
	2	65	93	93	93
Hearthstone	1	84	111	105	104
	2	88	105	99	107
		AUGUST			
Fish Creek	1	45	94	87	93
	2	44	96	89	96
Hearthstone	1	89	111	120	107
	2	94	110	103	107
Total	—	749	1,027	984	984

spondents per cell included the entire population available for that specific cell. A total of 3,744 camping parties responded to the four survey techniques.

ANALYSIS

Survey techniques were evaluated comprehensively. First, the total response to the sampling frame was analyzed. Then the response to individual questions in the handout and mailed methods and the response to the same items in the personal-interview method were compared and evaluated. All computations were performed on an IBM 1620 electronic digital computer.

Response to Sampling Frame

All four survey techniques were compared in terms of the percentage of total sampling frame obtained after each successive wave during 3 months at two parks. A three-factorial analysis of variance was used: 4 methods $\times$ 3 months $\times$ 2 parks (with 2 replications)—Model I, fixed effects. The percentage of respondents in each cell was transformed to the arcsin square root before analysis, as recommended by Snedecor (1959).

Orthogonal comparisons (Walker and Lev 1953) were used to compare personal-interview plus handout results with immediately mailed plus delayed mail results; personal interview with handout data; and immediately mailed with delayed mail results. Individual months also were compared orthogonally: June with the combined effects of July and August; and also July with August (table 2).

Response to Question Items

In the next phase of the analysis, replies to all questions were sorted into discrete categories. Then survey methods were compared, in percentage of respondents who answered individual items within each question. The items that were used as a basis for comparing survey techniques were those items answered most and least within each question of the personal-interview survey. An appropriate number of additional analyses was performed for several questions where more than two categories assumed a predominate and a minor position in the response spectrum.

Table 2.—*Analysis of variance within sampling-intensity categories, after transforming percentage of total response to four methods at two parks and three months to arcsin $\sqrt{}$ proportion*

Source of variation	D.f.[1]	Initial Sample		Initial sample +1 wave		Initial sample +2 waves		Initial sample +3 waves		Initial sample +4 waves	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Methods:[2]	3	5,824.79	—	2,757.24	367.14*	1,799.83	245.54*	1,378.57	208.87*	1,143.59	141.53*
1 + 2 vs 3 + 4	1	—	—	2,499.71	332.85*	1,852.69	252.75*	1,662.16	251.84*	1,474.86	182.53*
1 vs 2	1	—	—	5,765.07	768.65*	3,525.47	480.96*	2,473.56	374.78*	1,955.90	242.07*
3 vs 4	1	—	—	6.93	.92	21.34	2.91	.01	0.00	.01	0.00
Months:[3]	2	85.25	—	85.02	11.32*	70.87	9.67*	53.60	8.12*	37.15	4.60*
2 vs 3	1	—	—	1.45	.19	1.50	.20	6.40	.97	3.27	.40
1 vs 2 + 3	1	—	—	168.59	22.45*	140.24	19.13*	100.80	15.27*	71.02	8.79*
Parks	1	7.91	.97	.34	.05	1.90	.26	1.96	.30	.05	.01
Methods x months	6	25.76	3.17*	18.24	2.43	9.92	1.35	15.27	2.31	13.75	1.70
Methods x parks	3	9.60	1.18	4.13	.55	3.62	.49	1.43	.22	.14	.02
Months x parks	2	22.00	2.71	18.09	2.41	16.13	2.20	7.35	1.11	2.55	.32
Methods x months x parks	6	8.90	1.09	4.00	.53	7.05	.96	3.56	.54	6.34	.78
Error	24	8.13	—	7.51	—	7.33	—	6.60	—	8.08	—

[1] Degrees of freedom.

[2] Personal interview, handout, immediately mailed, and delayed mail methods are represented respectively by 1, 2, 3, and 4.

[3] June, July, and August are represented respectively by 1, 2, and 3.

* Indicates significance at the 95-percent probability level.

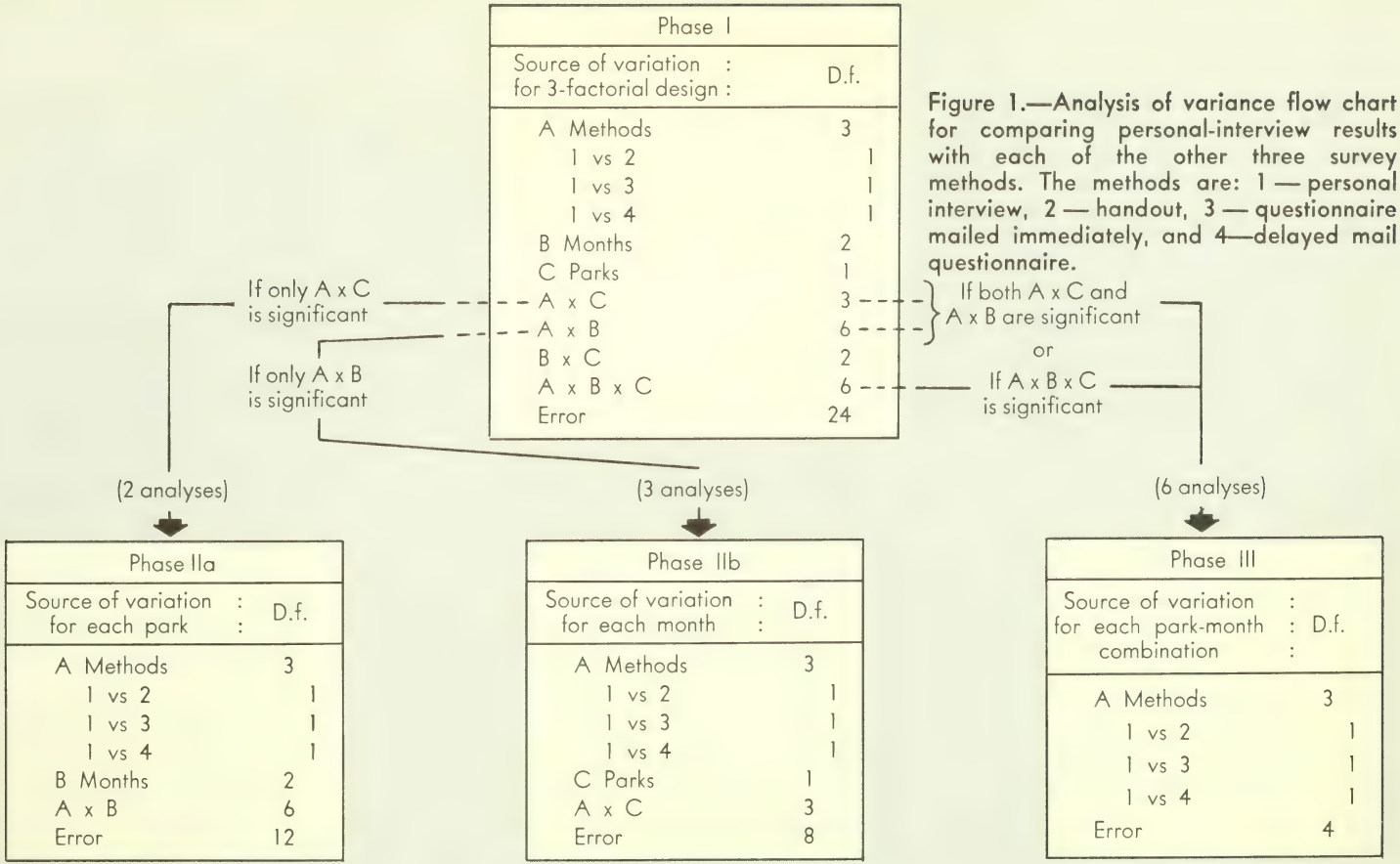

Phase I
Source of variation : for 3-factorial design : D.f.
A Methods 3
1 vs 2 1
1 vs 3 1
1 vs 4 1
B Months 2
C Parks 1
A x C 3
A x B 6
B x C 2
A x B x C 6
Error 24
If only A x C is significant
If only A x B is significant
If both A x C and A x B are significant
or
If A x B x C is significant
(2 analyses)
(3 analyses)
(6 analyses)
Phase IIa
Source of variation : for each park : D.f.
A Methods 3
1 vs 2 1
1 vs 3 1
1 vs 4 1
B Months 2
A x B 6
Error 12
Phase IIb
Source of variation : for each month : D.f.
A Methods 3
1 vs 2 1
1 vs 3 1
1 vs 4 1
C Parks 1
A x C 3
Error 8
Phase III
Source of variation : for each park-month combination : D.f.
A Methods 3
1 vs 2 1
1 vs 3 1
1 vs 4 1
Error 4

Figure 1.—Analysis of variance flow chart for comparing personal-interview results with each of the other three survey methods. The methods are: 1 — personal interview, 2 — handout, 3 — questionnaire mailed immediately, and 4—delayed mail questionnaire.

Initially a three-factorial analysis of variance—4 methods (A) $\times$ 3 months (B) $\times$ 2 parks (C)—was performed, using only initial sample data; then a three-factorial analysis using total sample data—that is, the initial sample data plus data from all four waves—was done. The quantity analyzed was the arcsin square root transformed percentage of respondents. Dunnett's test (1955) was used to make individual comparisons between the personal-interview results and the other three methods.

There were several directions that any one analysis could take, depending on the statistical significance of the first-order and second-order interactions.

If the second-order interaction (AxBxC) was significant, or if both the AxB and AxC interactions were significant, the computer executed analytical phase III. This phase consisted of an analysis of variance for a single classification (methods) within each of the six park-month combinations (fig. 1).

If only the AxC interaction was significant, then phase IIa of the analysis was performed. This phase consisted of a two-factorial analysis of variance (4 methods $\times$ 3 months) within each of the two classifications for parks (fig. 1).

An analytical phase IIb was used if only the AxB interaction was significant. This resulted in a two-factorial analysis of variance (4 methods x 2 parks) within each of the three classifications for months (fig. 1).

If none of the first- or second-order interactions was significant, the analysis was completed in phase I. This procedure used the error term of the initial three-factorial analysis to test for significant differences among survey methods (fig. 1).

RESULTS AND DISCUSSION

Total Response

Although handout and mailed surveys have been criticized because they usually elicit a small proportion of returns and because people react differently to this kind of survey than they do to a personal interview, we found that these two points did not affect our results appreciably.

The overall results of this study indicated that handout and mail surveys—with four waves for nonrespondents—provide results that are the same as personal-interview results in 75 to 87 percent of the questions. Delayed mail surveys, conducted 3 months after the camping experience, appear preferable to handout or immediate mail surveys.

The month in which a survey was conducted significantly influenced the percentage of total response within each sampling intensity (table 2).

In the initial sample, response to the three nonpersonal interview methods varied during the 3 months from 34 to 52 percent (fig. 2). Also, with the initial sample, the ranges of these values between methods (fig. 2) was smaller in August (42 to 46 percent) than in June (40 to 52 percent) and July (34 to 47 percent). This response pattern may help to account for the significant method x month interaction encountered with initial sample data (table 2). Interaction measures the failure of the percentage results among the survey methods to follow approximately the same trend each month; or, conversely, interaction measures the failure of percentage results when summarized for each month to follow approximately the same trend throughout all survey methods.

Total response to the personal-interview method remained consistently high (98 to 99 percent) at all parks throughout the summer (fig. 2).

During July and August, overall response to the three nonpersonal-interview methods was the same throughout each wave; however, response for June was significantly different from July-August results (table 2).

The combined response to personal interviews and handout questionnaires was always significantly greater than the combined response to the mailed surveys. Furthermore, the handout response was always smaller than the response to the personal interviews, but response to the two mailed surveys always remained about the same (table 2). In addition, although not compared statistically, the percentage response to the handout method within the various waves seemed consistent with corresponding values of the mail survey (fig. 2).

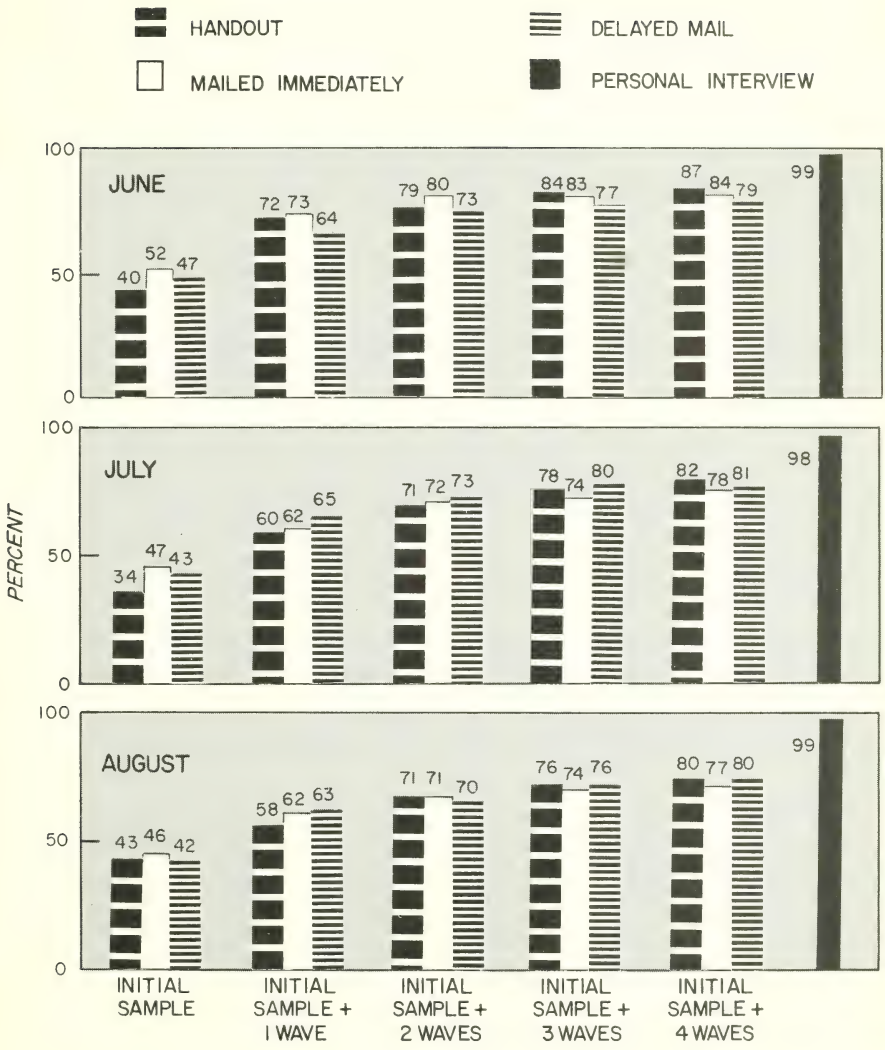


Figure 2.—Response to four survey-research methods that used the same questionnaire. An initial sample and four waves were used in the handout, immediately mailed, and delayed mail procedures. Bars indicate percentage of sampling frame obtained.

Maximum increases in total response were: 32 percent between the initial sample and the first wave (handout method in June); 13 percent from wave one to wave two (handout method in August); 7 percent between the second and third wave (handout and delayed mail methods in July); and 4 percent between wave three and four (fig. 2).

Individual Questions

Remember that percentage results of the personal-interview technique needed to differ by ± 8 to 10 percent or more from corresponding results of the less expensive survey techniques before personal interviews would be used by managers and planners for future surveys.

When initial sample data of all four survey techniques were compared in percentage of camping parties who answered individual question items, the immediately mailed results differed significantly from the control (personal interview) about 12 percent of the time. The delayed mail results disagreed significantly with the control data 22 percent of the time. However, these trends for the mail surveys were approximately reversed when additional data from all four waves were combined with the initial data. Results of the handout technique differed significantly from corresponding results of the control 19 percent of the time, regardless of sampling intensity (table 2).

Table 3.—*Percentage of question items in the handout and mailed survey methods that were significantly different from corresponding personal-interview data*

Survey method	Sampling intensity	
	Initial sample data only	Initial sample + 4 waves
	Percent	*Percent*
Handout	19.0[1]	19.0
Immediately mailed	12.5	25.0
Delayed mail	22.0	12.5

[1] For example, 19 percent of the question items in the initial sample of the handout method differed significantly from corresponding items in the personal-interview results.

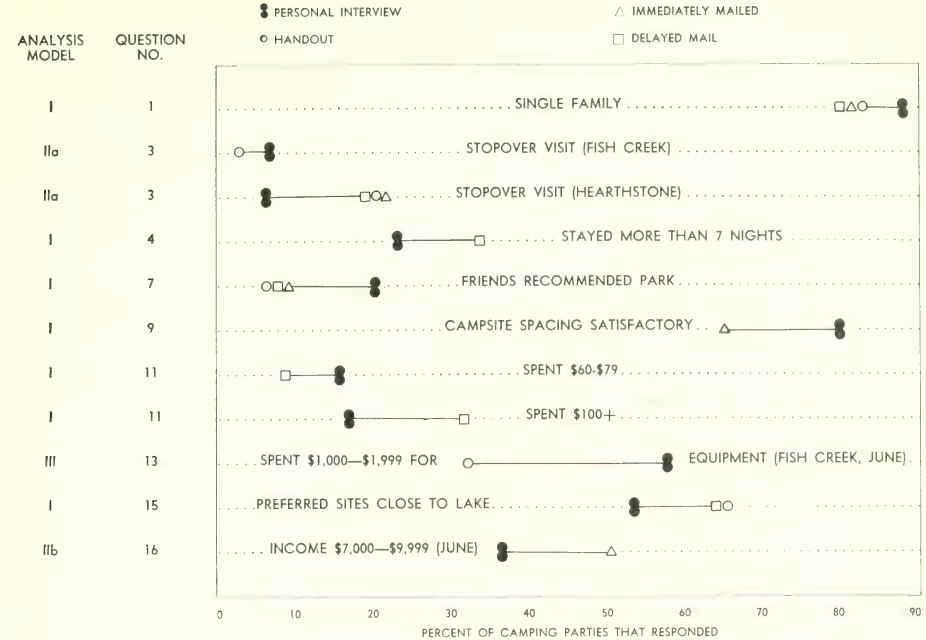
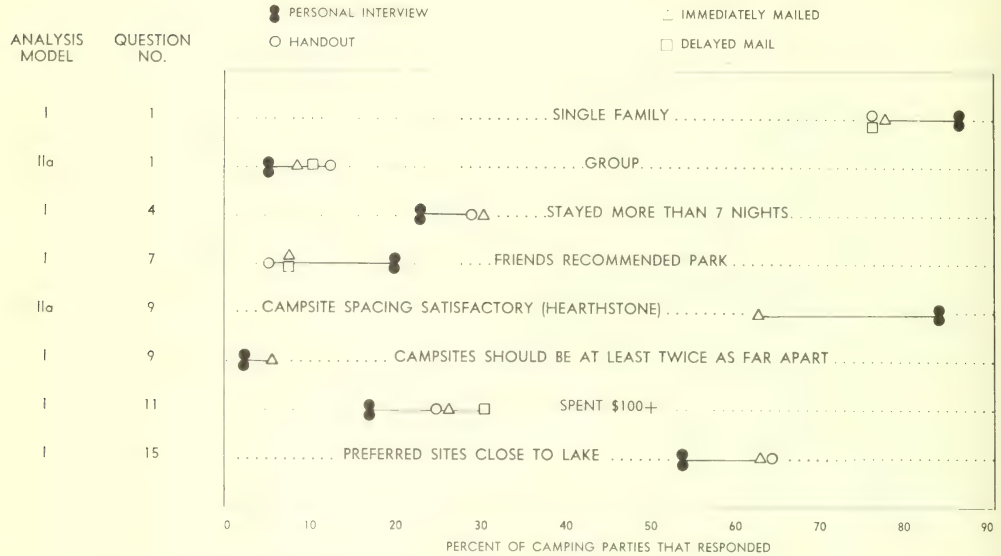

PERSONAL INTERVIEW
HANDOUT
IMMEDIATELY MAILED
DELAYED MAIL
ANALYSIS MODEL
QUESTION NO.
I 1 SINGLE FAMILY
IIa 3 STOPOVER VISIT (FISH CREEK)
IIa 3 STOPOVER VISIT (HEARTHSTONE)
I 4 STAYED MORE THAN 7 NIGHTS
I 7 FRIENDS RECOMMENDED PARK
I 9 CAMPSITE SPACING SATISFACTORY
I 11 SPENT $60-$79
I 11 SPENT $100+
III 13 SPENT $1,000—$1,999 FOR EQUIPMENT (FISH CREEK, JUNE)
I 15 PREFERRED SITES CLOSE TO LAKE
IIb 16 INCOME $7,000—$9,999 (JUNE)
0 10 20 30 40 50 60 70 80 90
PERCENT OF CAMPING PARTIES THAT RESPONDED
ANALYSIS-OF-VARIANCE MODELS USED TO DETECT SIGNIFICANT DIFFERENCES:
I = 4 METHODS X 3 MONTHS X 2 PARKS
IIa = 4 METHODS X 3 MONTHS
IIb = 4 METHODS X 2 PARKS
III = SINGLE CLASSIFICATION (PARKS)

Figure 3.—Questionnaire items in the initial response to handout or mailed surveys that differed significantly (at the 95-percent probability level) from personal-interview results.

Categories where significant differences in response occurred between the control and one or more of the other survey methods included: type of group, nature of visit, length of stay, reasons for camping, preferences for campsite spacing, trip expenditure pattern, equipment costs, preferences for campsite proximity to the lake, and income (figs. 3 and 4).

Regardless of sampling intensity, there were 8 to 10 percent fewer single-family camping parties in the nonpersonal interview methods than in the control (figs. 3 and 4). There were 4 to 8 percent more groups-of-friends in the handout and mail-survey results than in the control when all data were used for evaluating results (fig. 4).

In the percentage of campers who stayed 7 nights or longer, final results of the handout and immediately mailed methods were 6 to 8 percent greater than the control (fig. 4).


PERSONAL INTERVIEW
HANDOUT
IMMEDIATELY MAILED
DELAYED MAIL
ANALYSIS MODEL
QUESTION NO.
I 1 SINGLE FAMILY
IIa 1 GROUP
I 4 STAYED MORE THAN 7 NIGHTS
I 7 FRIENDS RECOMMENDED PARK
IIa 9 CAMPSITE SPACING SATISFACTORY (HEARTHSTONE)
I 9 CAMPSITES SHOULD BE AT LEAST TWICE AS FAR APART
I 11 SPENT $100+
I 15 PREFERRED SITES CLOSE TO LAKE
0 10 20 30 40 50 60 70 80 90
PERCENT OF CAMPING PARTIES THAT RESPONDED

ANALYSIS-OF-VARIANCE MODELS USED TO DETECT SIGNIFICANT DIFFERENCES:
I = 4 METHODS X 3 MONTHS X 2 PARKS
IIa = 4 METHODS X 3 MONTHS
IIb = 4 METHODS X 2 PARKS
III = SINGLE CLASSIFICATION (PARKS)

Figure 4.—Questionnaire items in the total response to handout or mailed surveys that differed significantly (at the 95-percent probability level) from personal-interview results.

One of the reasons campers gave for visiting the parks was that they were recommended by friends. Regardless of sampling intensity, this answer was given by a significant 12 to 15 percent greater number of respondents in the control than in the other methods (figs. 3 and 4). However, there was agreement between the control and the other survey methods concerning other reasons frequently mentioned for camping, such as nearness to water and swimming facilities available.

Preference expressed for present campsite spacing in the im-

mediately mailed survey was 20 to 40 percent less than the control results (figs. 3 and 4).

There was a 9 to 10 percent difference between control values and those of the other survey methods, when all waves were combined, regarding a desire to camp as close to the lake as possible (figs. 3 and 4).

Within the $100-plus stratum of the on-site expenditure category, final results of all self-enumerative techniques were 10 to 15 percent above the control value (fig. 4). Nonetheless, percentages in other strata of this cost distribution were about the same throughout the four survey methods.

Initial response in the $7,000 to $9,999 income bracket for the immediate mail survey was about 12 percentage points less than the control value (fig. 3).

Finally, for the handout technique, initial response in the $1,000 to $1,999 stratum for money spent on equipment was 26 percent lower than corresponding personal-interview results (fig. 3).

CONCLUSIONS

If a total response between 75 and 85 percent of a sampling frame is desired, handout and mailed techniques used in future recreation surveys that use the same type of questions as this study will need an initial sample and two to three waves for nonrespondents. Additional attempts to contact nonrespondents beyond the use of three waves results in only a minor response from the remaining, and seemingly impenetrable, component of the sampling frame. Conversely, if personal interviews are used, practically 100 percent of the sampling frame will be obtained in the initial sample.

Handout and mail-survey procedures can be expected to elicit about the same total response regardless of the intensity of sampling or the sampling location; but sampling periods throughout the summer may have a significant influence on the percentage of total response.

Handout and mail-survey techniques—with three to four waves for nonrespondents—generally seem to be reliable for obtaining

information of the type requested in this study, if an occasional 10 to 15 percent discrepancy from comparable personal-interview values is acceptable. However, if only a 5 to 10 percent differential can be tolerated, then the delayed mail procedure is recommended, except perhaps for questions that deal with large value categories, such as $100 or more spent while camping.

Because of the close similarities between most personal-interview and delayed-mail results, it seems very likely that most attitudes and impressions about pertinent facts surrounding the recreation experience do not change noticeably over a 3- to 5-month time interval immediately after the experience.

Since handout and mailed results for embarrassing questions about income and expenditure patterns or motivational reasons for camping (Backstrom and Hursh 1963) generally were the same as personal-interview results, the range of subject matter that could accurately be covered in future self-enumerative survey techniques in outdoor recreation seems quite broad and varied. The standard precautions and sampling procedures associated with handout and mail-survey techniques, as discussed by Boyd and Westfall (1964), Cochran (1953), and Payne (1951) should be followed.

■

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■

APPENDIX

Questionnaire Used for All Four Survey Techniques

DEAR ADIRONDACK CAMPER:

By answering this questionnaire, you will be helping us to make our campsites better places for you to visit.

If you have visited Fish Creek more than once this summer, please answer the questionnaire in relation to your longest visit.

When you have finished with the questionnaire, just drop it in the box labeled "Leave Questionnaire Here" at the camper registration office, or hand to a camp employee.

Thank you for your cooperation.

Note: If you forget to leave your questionnaire at the camping area, we will appreciate your mailing it to:

Forest Management Department
Camper Preference Survey
State University College of Forestry
Syracuse, New York, 13210

Bureau of the Budget No. 40-6439
Expires 3/31/65 Form No. 278

Greetings Camper

Will you please take a few minutes to tell us about your camping trip to Fish Creek Campground in 1964 and give us your preferences and opinions about campground facilities and design?

This 1964 Adirondack

Camper Preference Survey

is being conducted by the
N. Y. State Conservation Department
State University College of Forestry
United States Forest Service

Bureau of the Budget No. 40-6439
Expires 3/31/65 Form No. 278

Adirondack Camper Preference Survey

(No signature required--To be filled out by the head of household or head of camping group.)

1. Please check the TYPE OF GROUP which best describes your camping party at Fish Creek (check one):
( ) Single family
( ) Two or more families
( ) Group of friends
( ) Organized group (troop, team)
( ) One person alone

2. What was the NUMBER OF PEOPLE in your party for each of the following categories?

_____ Number of people over 18 years old

_____ Number of people between 12 and 18 years old

_____ Number of children under 12

3. What was the NATURE OF YOUR VISIT to Fish Creek?
( ) Vacation
( ) Week-end excursion
( ) Stop-over between two destinations
( ) Other purpose
What? _____

4. What was the TOTAL NUMBER OF NIGHTS you stayed?

_____ Nights

5. How many YEARS has the same group (which you checked in Question 1) camped together?

_____ Years

How many YEARS has the same group (which you checked in Question 1) camped at Fish Creek?

_____ Years

6. How many OTHER PUBLIC CAMPING AREAS has this same group used in New York State since you have been camping together?

_____ Number of camping areas

7. Are there any CHARACTERISTICS about Fish Creek or its LOCATION which influenced your decision to camp there this year?
( ) Yes ( ) No
If your answer is Yes, then: What was the MOST IMPORTANT factor about Fish Creek which influenced the decision to camp there?

_____

_____

_____

What was the SECOND MOST IMPORTANT factor?

_____

_____

_____

What was the THIRD MOST IMPORTANT factor?

_____

_____

_____

What was the FOURTH MOST IMPORTANT factor?

_____

_____

_____

8. When camping, what SIZE OF CAMPGROUND does your camping party prefer?
( ) Twice as large as Fish Creek
( ) About the same size as Fish Creek
( ) Half as large as Fish Creek
( ) Size of campground is not important to our camping experience
( ) Other
What? _____

Bureau of the Budget No. 40-6419
Expires 3/31/65 Form No. 278

9. When looking for a tentsite in a camping area, what SPACING BETWEEN TENTSITES does your camping party prefer?

( ) About the same distance apart as they are at Fish Creek.
( ) Closer than they are at Fish Creek.
( ) Twice as far apart as they are at Fish Creek.
( ) Greater than twice as far apart as they are at Fish Creek.
( ) Our camping party does not consider campsite spacing when selecting a tentsite--any spacing is satisfactory.
( ) Other
What?_____

10. If you had a choice, what amount of TREES and SHRUBS would your camping party prefer around its campsite?

( ) Completely surrounded by trees and shrubs so that your tentsite cannot be seen from other tentsites.
( ) Partially surrounded by trees and shrubs but your tentsite may be partially seen from other tentsites.
( ) Very few trees and shrubs surrounding your tentsite.
( ) Amount of trees and shrubs around the tentsite is not very important to camping experience.
( ) Other
What?_____

11. During your visit to Fish Creek, approximately HOW MUCH MONEY did your camping party spend for the following:*

	Amount
Lodging (Hotel and motel fees)	$_____
Camping fees	_____
Food	_____
Entertainment	_____
Gas, oil, etc. for car	_____
Other? _____	_____

*Do not consider any money spent to camp at other public camping areas--just consider the amount spent while staying at Fish Creek.

12. What is the MAXIMUM AMOUNT of MONEY you would spend for the same length of visit next year?

$_____ Total

13. For CAMPING EQUIPMENT used at Fish Creek this year, how much did you pay for:

	Equipment purchased within past five years.	Equipment rented this year.
Tenting equipment	_____	_____
Collapsible trailer	_____	_____
House trailer	_____	_____
Boat	_____	_____
Outboard motor	_____	_____
All other equipment (stove, sleeping bags, etc.)	_____	_____

14. Please RANK any 5 of the following items IN ORDER OF THEIR IMPORTANCE to your whole camping experience at Fish Creek. For example, if your party liked the swimming facilities best, the campsite design next, the facilities for securing food and supplies third, etc., the ranks 1, 2, 3 may be entered opposite each of these items, with 1 being the best liked; and then continue until you have ranked any 5 of the following items:

( ) Fishing facilities.
( ) Campground design and campsite spacing.
( ) Type and amount of trees and shrubs in the camping area.
( ) Swimming and water sports facilities.
( ) Availability of other recreational facilities and tourist attractions within a few hours drive from the camping area.
( ) Facilities for securing food and supplies.
( ) Sanitation and washroom facilities.
( ) Hiking opportunities near camping area.

15. In relationship to the lake, what TYPE OF CAMPGROUND would your party prefer if they had their choice? (check one)

( ) All tentsites as close to the lake as possible.

( ) All tentsites partially screened from the lake.

( ) All tentsites completely screened from the lake so that none are visible from the lake.

16. Would you please check your annual net income before taxes for husband and wife combined? (To be filled out only by heads of family groups.)

( ) $ 0 to 3,999
( ) 4,000 to 6,999
( ) 7,000 to 9,999
( ) 10,000 or more

17. If you have any additional comments or criticisms regarding your camping visit to Fish Creek, please feel free to list them below:

Thank you for your interest.
We hope to see you again.

Bureau of the Budget No. 10-6439
Expires 3/31/65 Form No. 248

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FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

Harvesting Costs & Returns Under
4 CUTTING METHODS
in Mature Beech-Birch-Maple Stands in New England

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by Stanley M. Filip

U. S. FOREST SERVICE RESEARCH PAPER NE-87
1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

The Author

STANLEY M. FILIP received his forestry training at The Pennsylvania State University. After working several years in consulting, industrial, and farm forestry, he joined the Northeastern Forest Experiment Station of the U. S. Forest Service as a research forester in 1946. Most of his research work has been in timber management, mainly with beech-birch-maple stands in Pennsylvania and New Hampshire. He is now on the staff of the Experiment Station's research unit at Durham, N. H.

Harvesting Costs & Returns Under 4 CUTTING METHODS in Mature Beech-Birch-Maple Stands in New England

■

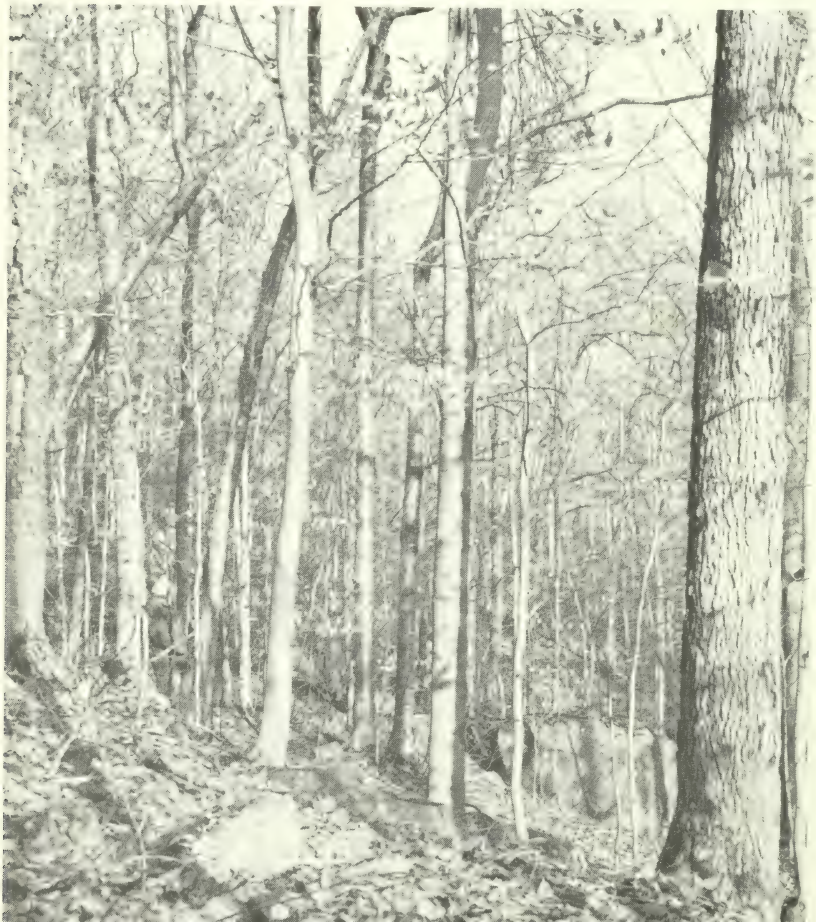
BEECH-birch-maple forests in New England are adaptable to a variety of cutting methods. The silvicultural implications of these different methods have been frequently studied and reported *(Blum and Filip 1963, Gilbert and Jensen 1958, Jensen 1943, Marquis 1965b)*. But, the costs and returns associated with logging under the various cutting methods have not been adequately studied.

Recognizing the need for combined silvicultural and economic information of this type, the Northeastern Forest Experiment Station began a timber-management study on the Bartlett Experimental Forest in New Hampshire in 1950. Many years will be required to fully evaluate this long-term study, but preliminary information is now available about logging costs and returns, production rates, and products obtained from initial harvests made by four different cutting methods.

STUDY METHODS

Four cutting methods—selection, patch, diameter-limit, and commercial clearcutting—are being compared on compartments large enough to simulate commercial-size logging operations. Five separate logging contractors were involved in these cuttings over a 14-year period (1950 to 1963). Unfortunately, not all of these contractors operated under all four cutting methods. However, all operated in fairly similar stands, followed the same merchantability standards, practiced tree-length skidding and multi-product utilization, and sold products to essentially the same industries. All used one-man chain saws and crawler tractors.

Figure 1.—A typical stand of mature beech-birch-maple timber in which the cuttings were made. Scattered boulders and steep slopes are common in this region.



All cuttings were made in previously unmanaged stands (fig. 1). These stands had been high-graded several times between 1870 and 1900—first for spruce and later for the better sugar maple and yellow birch. Some large hemlocks were also removed about 1918.

When the compartment study was begun in 1950, beech—which had never been cut heavily—made up over 50 percent of the gross volume. The stands were of low overall quality and vigor, but they did contain some thrifty trees of the high-value species: sugar maple, yellow birch, paper birch, and white ash. Trees of all species ranged in size from saplings to occasional stems of more than 30 inches diameter at breast height. The merchantable sawtimber volume averaged about 9,000 board feet per acre, and total merchantable volume averaged about 2,300 cubic feet per acre.[1]

All compartments were situated on mountainous terrain at elevations between 900 and 2,200 feet above sea level. Slopes averaged between 10 and 25 percent, but steeper pitches up to 40 percent were common. Large and small granite boulders were prevalent.

Cutting Methods

Selection cutting.—The long-term aim under selection cutting is to develop and maintain an all-aged distribution of vigorous high-quality trees. Individual trees were marked for removal in all size classes larger than 5.0 inches d.b.h. As a rule, the marked volume represented about 20 to 30 percent of the initial cubic-foot volume. Because these stands contained many defective trees, the first cutting under this method was primarily for salvage and stand improvement. Eleven compartments, totaling 423 acres, were included in the selection cutting method.

Patch cutting.—Patch cuttings are clearcuttings of small areas intended to favor the regeneration of yellow and paper birch. Patches in this study ranged from 1/10 to 2/3 acre and were

[1] Board-foot volumes are based on International log rule, ¼-inch kerf, for hardwoods over 11.0 inches d.b.h. and for softwoods over 9.0 inches d.b.h. Sawtimber trees averaged 14 inches d.b.h. with two 16-foot logs. Total cubic-foot volumes are based on trees over 5.0 inches d.b.h.

generally laid out in portions of the stand that contained groups of mature, overmature, or defective timber. All merchantable trees over 5.0 inches d.b.h. within the patch were harvested. Four compartments, totaling 120 acres, were cut by this method. Within this area, 38 patches were cut, totaling 16 acres.

Diameter-limit cutting. — All merchantable trees over 13.0 inches d.b.h. were harvested.[2] In addition, practically all paper birch trees (including trees down to 7.0 inches d.b.h.) were harvested because they were mature or overmature and would not last until the next cutting cycle. Under this diameter-limit specification, 55 percent of the initial board-foot volume and 52 percent of the initial cubic-foot volume were harvested. Two compartments, totaling 80 acres, were cut by this method.

Commercial clearcutting.[3]—This method usually involves a harvest of all merchantable trees. The stand remaining after the harvesting operation will vary according to available markets and the product objective of the contractor. In our study, nearly all of the board-foot volume and 82 percent of the cubic-foot volume were removed. The volume remaining was in poletimber trees 5.0 to 9.0 inches d.b.h. and in trees of all sizes that were highly defective. One compartment of 41 acres was cut by this method.

Skid Roads

Except for the compartment handled as a commercial clearcutting, the main skid-road system was laid out by a research forester before logging. Long steep grades, abrupt curves, and wet spots were avoided wherever possible. Streams and stream beds were crossed at right angles in most places.

The compartment handled as a commercial clearcutting had no planned road system. Instead, the contractor was given a free hand to locate the skid roads as he wished. Generally, he devel-

[2] A 13-inch diameter limit was chosen to strike a fairly even balance between the volume of growing stock cut and the amount retained for further growth and development. In other hardwood stands this limit may be higher or lower to attain the same objective.

[3] This method differs from the clearcutting method recommended by Gilbert and Jensen (1958) primarily because the stand was not completely removed by harvesting and follow-up cultural work.

Figure 2.—Four to six tree-lengths made up a full tractor-arch skidding load. The tree-lengths ranged from 15 to 50 feet and averaged about 35 feet.

oped the necessary roads as the logging operation progressed. Perhaps because of this, much of the road system was poorly located for efficient skidding.

Skidding costs for the selection, patch, and diameter-limit cuttings—but not for the commercial clearcutting—include the construction of water-diversion ditches installed at the completion of the operation. Such after-logging care helps to prevent erosion and gullying and can be accomplished at moderate cost *(Trimble and Barr 1960, Weitzman 1952, Trimble et. al. 1957)*.

Logging and Markets

Each compartment in the study was considered a distinct logging chance, having its own skid-road system and landing sites. Only two of the 18 compartments covered in this report were not located along a truck road. However, adjustments in labor

Figure 3.—Multi-product utilization. The tree-lengths were bucked at roadside landings to yield the highest product returns: logs, millwood, and pulpwood in order of priority.

and equipment hours were made to compensate for the travel time beyond the compartment boundary.

The size of the logging crews varied from two to six men, depending on the job at hand. Most frequently, the contractors preferred to use a four-man crew: one faller, one skidding operator, and two buckers. Even though the men were assigned specific tasks, they frequently helped one another to avoid delays.

Felled timber was skidded in tree-lengths to the landings. Skidding distance seldom exceeded 1,500 feet and averaged less than 1,000 feet (fig. 2).

Cutters bucked trees to yield the highest possible returns (fig. 3). High-value products included paper birch and yellow birch millwood, mixed hardwood logs for veneer and core stock, white ash logs for handle stock, mixed hardwood dowel stock,[4] and

[4] A dowel-stock market has been available only in the most recent sales on the Experimental Forest. However, some of the 8- and 10-inch diameter beech and sugar maple trees converted into pulpwood in past sales covered by this report would have been satisfactory as dowel stock. Based on field checks, about 10 percent of the hardwood pulpwood would have met the dowel-stock specifications. Hence the standard cords of hardwood pulpwood actually sold were reduced by 10 percent, and this 10 percent was considered as a dowel-stock product in each method of cutting.

softwood sawlogs. Merchantable material that did not meet specifications for these products was bucked into pulpwood.

The buckers stacked the short products—pulpwood and millwood—by hand, but the skidder helped to deck most of the logs with the tractor winch or blade.

Records

On each compartment, daily records were kept for each man and the particular phase of the operation in which he was engaged. The elapsed time for men and equipment was recorded in the following three categories:

Cutting.—This included man-hours of felling, limbing, topping, and bucking; decking or stacking products at roadside; preparing and bulldozing landings; refueling chain saws; sharpening the saw chain; travel within the compartment; and rest periods.

Skidding.—This included man-hours of hooking, skidding, and unhooking tree-lengths; swamping and bulldozing skid roads and trails; bulldozing water-diversion ditches; and rest periods.

Tractor.—This included elapsed hours for bulldozing skid roads, trails, and landings; skidding tree-lengths; decking products at roadside; daily lubrication; and minor repairs. The operator's time for bulldozing landings and decking products was most appropriately placed under cutting labor, because this type of work was considered most helpful to the fallers and buckers. Then too, the tractor operator, fallers, and buckers worked so closely together on these tasks that it was impractical to record the time in more than one category.

Final evaluations of cutting and skidding labor were made in man-hours, even though some men were paid on a piece-rate basis and others on an hourly-basis within the same compartment.

To use a basic measurement for the combination of products harvested and the various scaling rules used, a unit of 100 cubic feet was selected. Such a unit of measurement is generally referred to as a cunit. Approximate conversions to cunits were made as follows:

Product	Scale	Cunits
Logs	1,000 board feet*	1.47
Ash handle stock	1,000 board feet*	1.47
Birch millwood	Standard cord	.88
Dowel stock	Standard cord	.88
Pulpwood	Standard cord	.83

* Based on International log rule, ¼-inch kerf.

Current local wage and equipment rates were applied to determine harvesting costs.[5] Likewise, the best estimate of current local prices paid by the nearest markets for the various products was used to determine harvesting returns. Loading and truck hauling costs were deducted from delivered prices to appraise product values at compartment roadside. The scale of products was based on mill tally slips. Applied rates for labor and equipment were as follows:

Item	Rate
Labor (including fringe benefits)	$2.50 per man-hour
Chain saw (one-man type) and hand tools	1.20 per cunit
Tractor (40-60 H.P.), winch, and arch	4.50 per elapsed hour

The following roadside product prices were used to evaluate roadside returns:

Product	Price Per 1,000 board feet
Hardwood logs:	
Red oak	$100
Yellow birch	100
Paper birch	110
Sugar maple	100
Red maple and beech	50
Ash handle stock	65
Softwood logs:	
Red spruce	50
Eastern hemlock	40
	Per standard cord
Birch millwood	$ 33
Dowel stock	25
Hardwood pulpwood	13

[5] Costs of marking the individual trees or patches to be harvested have not been included in this report. However, since selection and patch cutting involve marking costs, and diameter-limit and clearcutting do not, this factor will also affect the overall cost-return relationships of the various methods.

RESULTS

Products

The volume of products harvested by each cutting method is given in table 1. Over half of the yield in the selection and patch cuttings was in pulpwood—55 and 57 percent, respectively (fig. 4). The trees marked for removal in the selection cutting generally were those of the poorest quality in the stands. Similar poor-quality trees were removed in the patch cutting as a result of the patch locations; the patches were deliberately laid out in portions of the stand that contained a high proportion of defective trees. In effect, both cuttings were stand-improvement operations. Future cyclic cuts should yield less pulpwood and a higher proportion of the high-value products. Nevertheless, if multi-product utilization is continually practiced, at least one-third of future yields will probably be in pulpwood or a similar low-value bulk product.

Because of the heavy cutting of sawtimber-size trees, the diameter limit and commercial clearcutting methods yielded a large proportion of high-value products. In the diameter-limit cutting, the yield in high-value products amounted to 70 percent; in commercial clearcutting the yield was 59 percent.

Table 1.—*Total harvested volume, by product and method of cutting*

Product	Selection cutting	Patch cutting	Diameter limit	Clear-cutting
Hardwood logs (board feet)[1]	392,135	48,645	236,675	128,485
Softwood logs (board feet)[1]	74,580	11,405	77,460	57,450
Ash handle stock (board feet)[1]	8,620	1,800	2,630	20,155
Birch millwood (standard cords)	187.80	23.50	90.24	58.92
Dowel stock (standard cords	162.83	69.12	80.53	91.37
Pulpwood (standard cords)	1,465.48	276.47	322.10	365.50
Total in cunits	2,223.7	401.9	879.2	734.0
Average per acre (cunits)[2]	5.3	3.4	11.0	17.9
Percent in pulpwood	55	57	30	41

[1] Board-feet, International log rule, ¼-inch kerf.

[2] Based on compartment acreages.

Figure 4.—The yield in pulpwood was high in the four cutting methods.

Production

The average labor input per cunit was fairly uniform among three of the cuttings: selection, patch, and commercial clearcutting (table 2). The diameter-limit cutting averaged about 1 man-hour per cunit lower than the others. In all cutting methods, about two-thirds of the labor input was for cutting; one-third was for skidding.

The tractor time per cunit did not vary much among cutting methods.

The output per man-day averaged about 1¾ cunits for the selection and patch cuttings and for the commercial clearcutting. In the diameter-limit cutting, production averaged about 2¼ cunits per man-day—nearly 29 percent higher. This higher production resulted mostly from a combination of higher average tree size and better quality trees harvested. Others have found that tree size had an important bearing on *cutting time in hardwood* stands *(Campbell 1953, Jiles and Lehman 1960).*

Table 2.—*Physical inputs and outputs*

Item	Selection cutting	Patch cutting	Diameter limit	Clear-cutting
Labor per cunit:				
Cutting (man-hours)	3.17	3.15	2.22	3.01
Skidding (man-hours)	1.40	1.52	1.29	1.41
Labor input (man-hours)	4.57	4.67	3.51	4.42
Tractor use per cunit:				
Cutting (elapsed hours)	0.04	0.05	0.11	0.02
Skidding (elapsed hours)	1.07	1.04	1.07	1.20
Tractor input (elapsed hours)	1.11	1.09	1.18	1.22
Production:				
Output per man-day (cunits)	1.75	1.71	2.28	1.81
Output per man-hour (cunits)	.22	.21	.29	.23

Cost and Return Analysis

The average dollar cost to harvest a cunit of product was nearly identical in the selection, patch, and commercial clearcutting (table 3). The lowest cost was in the diameter-limit cutting, where the cost averaged more than $2 per cunit less than the others.

The cutting phase accounted for slightly more than half the cost per cunit in the selection and patch methods, and slightly less

Table 3.—*Dollar costs per cunit of product harvested*

Work phase	Selection cutting	Patch cutting	Diameter limit	Clear-cutting
Cutting:				
Labor	$7.93	$7.81	$5.55	$7.53
Chain saw	1.20	1.20	1.20	1.20
Tractor[1]	.18	.23	.50	.09
Subtotal	9.31	9.30	7.25	8.82
Skidding:				
Labor	3.50	3.80	3.23	3.53
Tractor	4.82	4.68	4.82	5.40
Subtotal	8.32	8.48	8.05	8.93
Total costs	17.63	17.78	15.30	17.75

[1] Bulldozing landing sites and decking products.

Table 4.—*Summary of dollar costs, returns, and conversion surplus per cunit of product harvested*

Cutting method	Costs	Returns	Conversion surplus[1]
Selection cutting	$17.63	$26.77	$ 9.14
Patch cutting	17.78	26.28	8.50
Diameter limit	15.30	38.19	22.89
Clearcutting	17.75	31.12	13.37

[1] Balance for stumpage, supervision, and profit.

than half in the diameter-limit cutting. In the commercial clearcutting, the average cost was about evenly divided between cutting and skidding.

Dollar returns per cunit were about the same in the selection and patch cuttings, both of which averaged much lower than the other methods (table 4). The lower returns resulted from differences in the quality and value of the harvested products. Under the selection and patch methods, the initial cuttings were essentially stand-improvement operations, which removed many poor-quality trees. On the other hand, the bulk of the cut in the diameter-limit and commercial clearcutting methods was in better quality trees that yielded products of higher value. However, in all cuttings returns exceeded costs. The balance per cunit for stumpage, supervision, and profit—conversion surplus—ranged from $8.50 per cunit in patch cutting to $22.89 per cunit in the diameter-limit cutting.

DISCUSSION

Harvesting costs and returns—and hence profit margins—tend to vary from one operating unit to another. The efficiency of the logging crew, especially the judgment and experience of the logging foreman, is a major factor. Timber size, species, and quality are also important determinants of costs and returns. Likewise, the type of equipment used will affect costs; costs will probably be reduced in the future because of the steady improvements in

cutting and skidding equipment now taking place. Labor-payment methods—hourly, piece, or bonus—also have an effect on costs.

A forest managed on an uneven-aged basis with periodic selection cuttings might never differ radically from the unmanaged stands in this study. Minor differences that might be expected would include a gradual improvement in quality during the next few harvest cuttings and a trend toward higher proportions of the tolerant species such as sugar maple and beech *(Filip and Leak 1962, Leak and Wilson 1958)*.

On the other hand, a forest managed under an even-aged system with clearcutting would differ considerably from these unmanaged stands. The proportion of intolerant and intermediate species such as paper birch, yellow birch, and white ash would be higher *(Blum and Filip 1962, Leak and Wilson 1958, Marquis 1965a)*. Quality would vary with the intensity of management. With moderately intensive management, utilizing control of undesirable stems, and a program of periodic thinnings, the size distribution, species composition, quality, and volume of material removed throughout a rotation would bear little semblance to the harvest reported here.

Thus these logging cost and return data must not be extended beyond their intended application. These data apply to initial harvests in previously unmanaged old-growth northern hardwood stands; they are only indicative of the range of values that might be expected on similar logging operations in similar stands, and they do not reflect long-term cost-return ratios under various systems of forest management.

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Acknowledgment

The author gratefully acknowledges the help received from Merle C. Grant in preparing the office report from which material for this publication was selected. At the time of the study Mr. Grant was forestry research technician with the Northeastern Forest Experiment Station at Bartlett, N. H. He is now an administrative assistant in the Station's research unit at Parsons, W. Va.

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Richard D. Lane, Director

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DAVID G. MARTENS received his Bachelor of Science degree in forest products from Iowa State University in 1961 and his Master's degree in wood technology from the same institution in 1963. In 1960-61 he worked for the Wood-Mosaic Corp., Louisville, Ky. He joined the staff of the Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, W. Va., in 1963; and since August 1964 he has been in charge of flooring studies at the Laboratory.

WHAT'S HAPPENING TO THE SAWMILLS?

IF THE VALUE of hardwood lumber had increased at the same rate as the cost of producing it, the countryside would not be dotted with the remnants of so many abandoned sawmills. This is especially true in the Appalachian region, where some 2,800 sawing and planing mills (about 40 percent of the operating plants) went out of business during the period 1948-58. And this trend is still continuing.

In general, the very large and the very small mills are disappearing and the intermediate-size mills are becoming more mechanized and automated. But even with improved efficiency, most mills are experiencing a declining margin between operating costs and income. Therefore it has become imperative for sawmill owners and operators to be more cost-conscious and to obtain a better understanding of their particular cost-profit situations.

One way to achieve this understanding would be through a better estimation of true sawlog value and a more precise knowledge of how changing hardwood lumber prices affect sawlog value.

In 1964, the U.S. Forest Products Marketing Laboratory of the Northeastern Forest Experiment Station began evaluating

the changes in hardwood lumber prices in relation to their effect on the Appalachian hardwood sawmill industry. The thought was that such a study might provide additional clues to the causes of the rapid decline in the number of operating sawmills and the generally unfavorable rate of profit in this industry.

Sawlogs were selected as a basis for analysis because researchers at the Laboratory wanted to determine the composite change in value for all lumber produced from each grade and species of log over the 10-year period, 1955-64—not just the change in value of certain lumber grades.

They recognized that changes in price of any individual grade of lumber have only a limited influence on the total lumber value recovered from a log; but, by calculating the combined dollar value of all lumber grades recovered from a log, they were able to measure the total effect of lumber price changes according to the proportion of the log that the grades represent.

STUDY TECHNIQUES

The product value of any sawlog is determined from the combined value of the products that can be produced from it; in this case, factory-grade lumber. If we knew the proportion of lumber of each grade contained in a log and the market prices from lumber of those grades, we could then determine the weighted-product value or lumber-recovery value.

In our study, we selected the U.S. Forest Products Laboratory hardwood log grades from standard lumber as the basis for evaluating log quality. A description of these log grades—and tables of lumber-grade-yields by species, diameter, and grade of log—is provided in Forest Products Laboratory Report D1737.[1]

We have found that the average predicted lumber-grade yields in Report D1737 are exceptionally accurate for factory-

[1] United States Forest Products Laboratory. HARDWOOD LOG GRADES FOR STANDARD LUMBER. U.S. Forest Serv. Forest Prod. Lab. Rpt. D1737. 66 pp., illus. 1959.

lumber-grade logs of the species covered in our study. Preliminary results from a study conducted by the Forest Products Marketing Laboratory at Appalachian sawmills, using the log grades in Report D1737, indicated that predicted grade yields of Common-and-Better lumber were generally within 1 percent of actual lumber yields. [2]

The *Hardwood Market Report* [3] was selected as the source of lumber prices for our study. We believe that it represents the most widely accepted list of lumber-price quotations for the Appalachian Region. The *Hardwood Market Report* prices represent estimates of average regional lumber prices in carload quantities of random widths and lengths, rough, air-dried, f.o.b. mills, Johnson City, Tennessee area.

By using the hardwood log grades for standard lumber, with their associated average lumber-grade-yields, and the published lumber prices, we were able to calculate lumber-recovery values for each major species and log grade of Appalachian hardwood sawlogs. After the lumber-recovery values were tabulated, they were plotted for the 1955-64 study period and the resulting line graphs were analyzed and compared with the hardwood-lumber price curves.

LUMBER-RECOVERY VALUE

The lumber-recovery value represents the value of lumber that can be sawed from the average sawlog of a given log grade and species. This recovery value is determined by multiplying the predicted average lumber-grade-yields for the log grade by the respective lumber prices and then summing these products.

An illustration of calculations for grade-3 red oak sawlogs is given in table 1. The lumber-grade yield data used represents the average for grade-3 red oak logs from Report

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[2] Data on file at Forest Products Marketing Laboratory, NE. Forest Exp. Sta., U.S. Forest Serv., Princeton, W. Va.

[3] Hardwood Market Report. WEEKLY LUMBER NEWS LETTER, published by Abe Lemsky, Memphis, Tennessee. Vols. 22-21. 1954-64.

Table 1.—Sample determination of lumber-recovery values for grade 3 red oak sawlogs [1]

Lumber grades	Grade yield	Lumber price	Product value
	Percent	*Dollars/ M bd. ft*	*Dollars/ M bd. ft.*
First-and-Seconds	0.8	200	1.60
Selects	.6	190	1.14
No. 1 Common	16.8	108	18.14
No. 2 Common	23.8	77	18.34
No. 3A Common	12.2	67	8.17
No. 3B Common	43.5	34	14.79
Timbers & Sound Square Edge	2.3	67	1.54
Total	100.0		63.72

Lumber-recovery value for grade 3 red oak logs would be $63.72 per thousand feet board measure under the quoted lumber values used in this illustration.

D1737. By this method the lumber-recovery value for sawlogs of a stated grade and species is determined in terms of dollars per thousand feet, board measure.

Board measure is used because lumber-recovery values for sawlogs deal with the volume of lumber actually sawed from the logs. However, if log-rule volumes are used in conjunction with lumber-recovery values to estimate sawlog value, overrun must be taken into account. For instance, if for a given group of grade-3 red oak logs the expected overrun amounted to 25 percent and the average lumber-recovery value was $64.68, the value of these logs would be calculated at $64.68 times 1.25, or $80.85 per thousand board feet, log-rule estimate.

It should also be noted that all lumber-recovery values calculated in this study represent the average for the respective log grades. We realize that some sawmills saw only the larger logs of certain grades; so some sawmills experience above-average lumber-recovery values. Sawmill managers can determine their correct lumber-recovery values by calculating weighted averages of the lumber-grade yield figures found in Report D1737 for the log diameters they use.

LUMBER-RECOVERY VALUE CHANGES

The trends in hardwood lumber-recovery values, based on Appalachian species and log grades, indicate that very little increase in sawlog product value occurred during the period 1955-64. The trends of lumber-recovery values in dollars per thousand board feet for log-grades 1, 2, and 3 of the major Appalachian species are shown in figures 1 to 11.

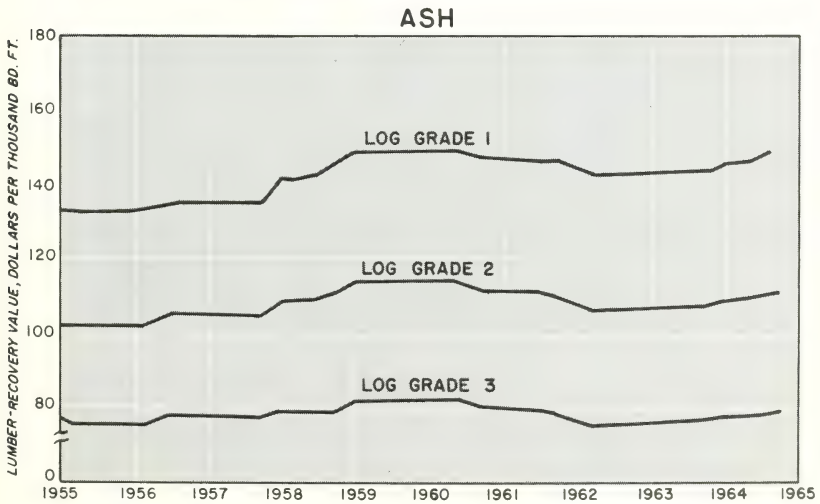

Figure 1.—Trends in lumber-recovery values for ash sawlogs in the Appalachian region, by log grades, 1955-64.

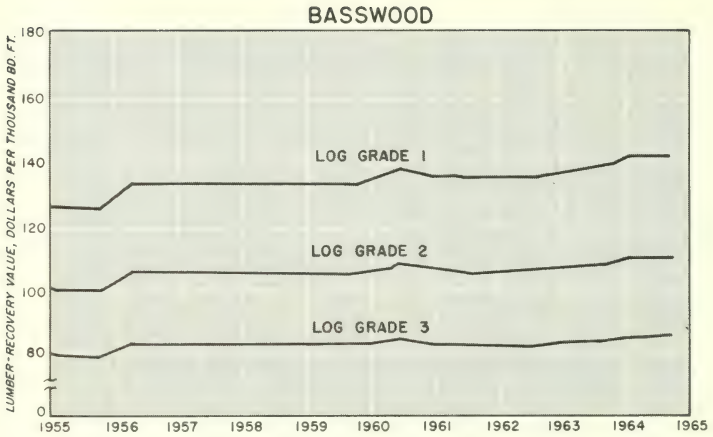

Figure 2.—Trends in lumber-recovery values for basswood sawlogs in the Appalachian region, by log grades, 1955-64.

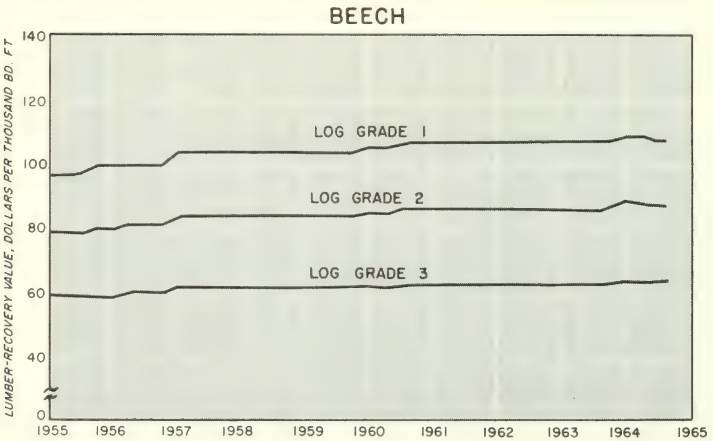

Figure 3.—Trends in lumber-recovery values for beech sawlogs in the Appalachian region, by log grades, 1955-64.

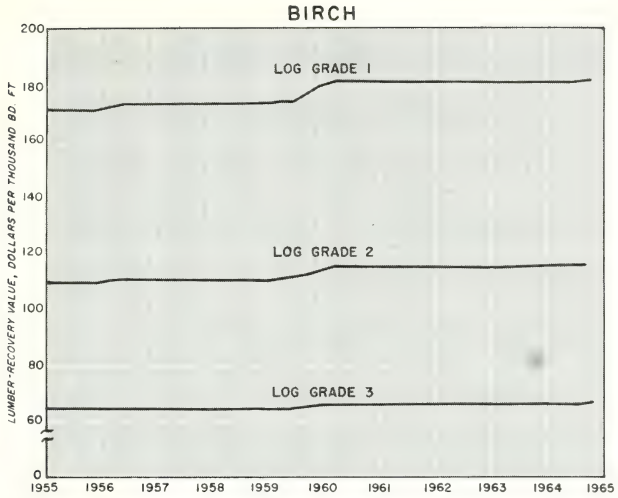

Figure 4.—Trends in lumber-recovery values for birch sawlogs in the Appalachian region, by log grades, 1955–64.

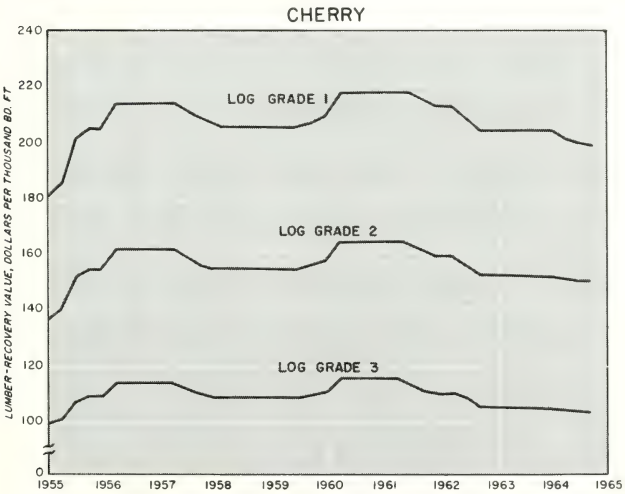

Figure 5.—Trends in lumber-recovery values for cherry sawlogs in the Appalachian region, by log grades, 1955-64.

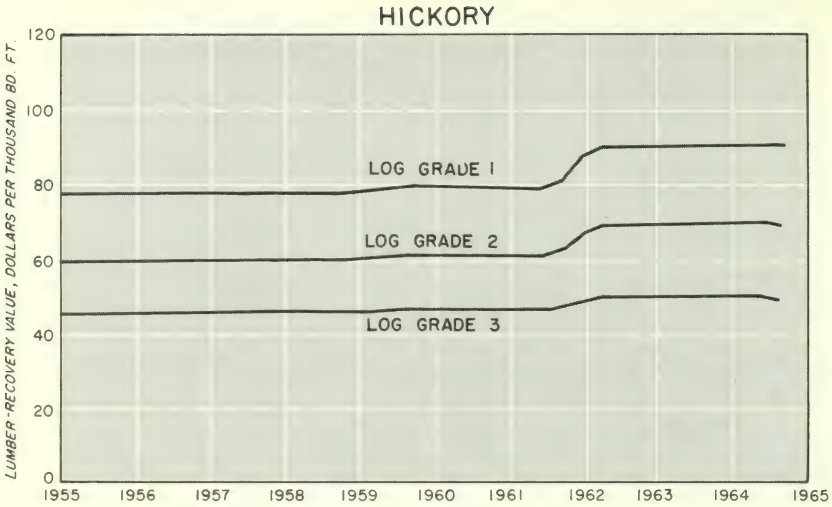

Figure 6.—Trends in lumber-recovery values for hickory sawlogs in the Appalachian region, by log grades, 1955-64.

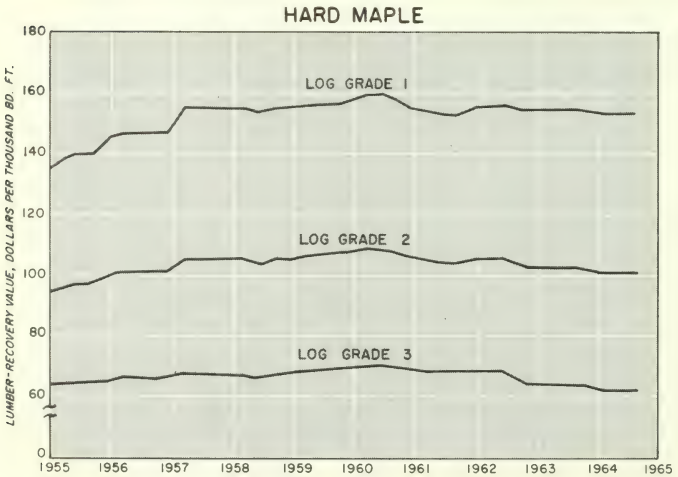

Figure 7.—Trends in lumber-recovery values for hard maple sawlogs in the Appalachian region, by log grades, 1955-64.

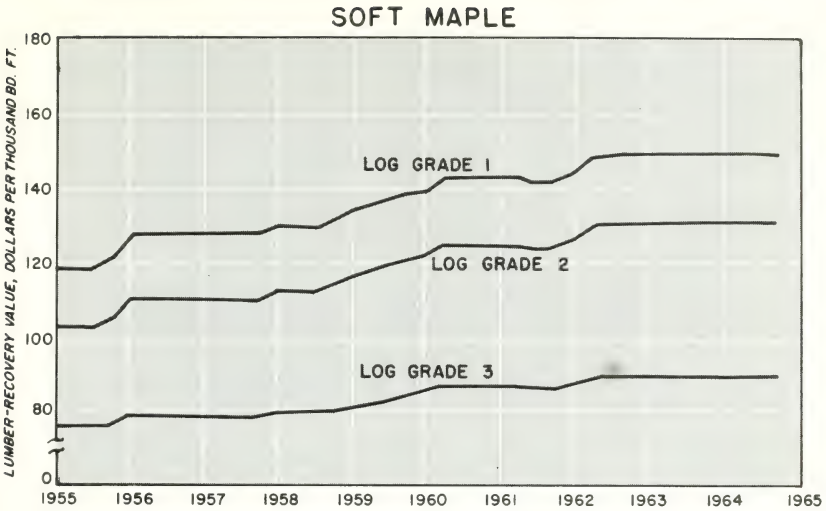

Figure 8.—Trends in lumber-recovery values for soft maple sawlogs in the Appalachian region, by log grades, 1955-64.

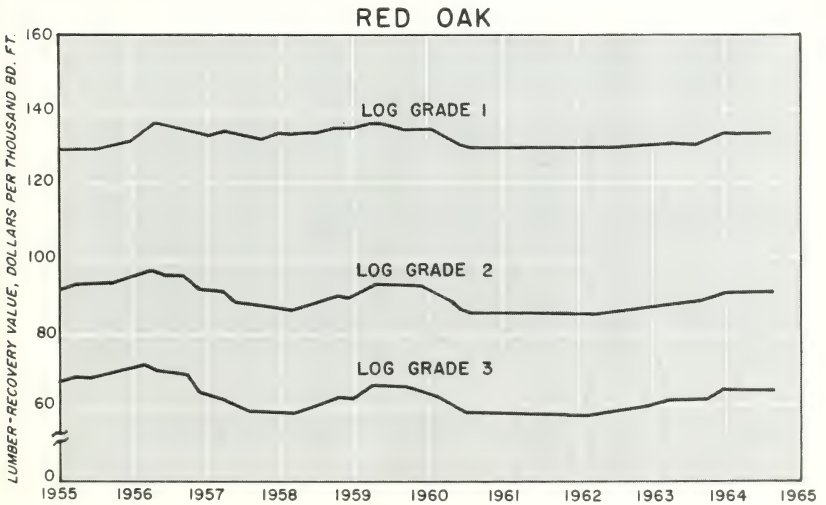

Figure 9.—Trends in lumber-recovery values for red oak sawlogs in the Appalachian region, by log grades, 1955-64.

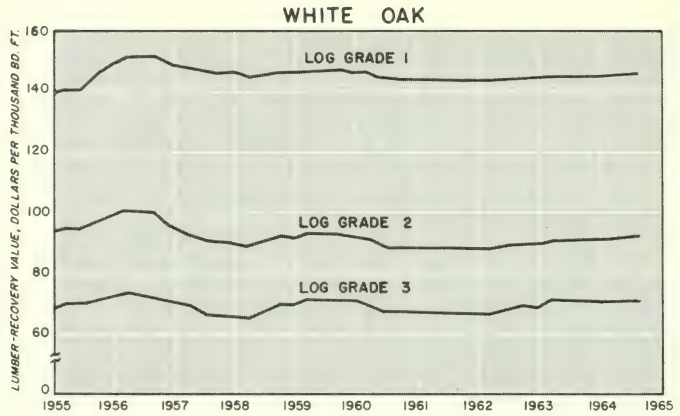

Figure 10.—Trends in lumber-recovery values for white oak sawlogs in the Appalachian region, by log grades, 1955-64.

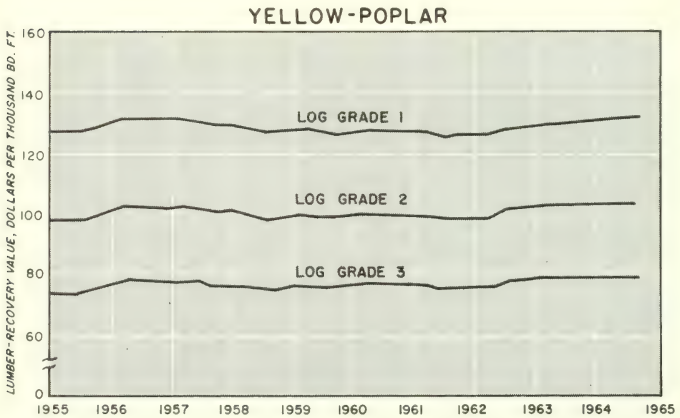

Figure 11.—Trends in lumber-recovery values for yellow-poplar sawlogs in the Appalachian region, by log grades, 1955-64.

Relatively little fluctuation occurred in the lumber-recovery values of most log grades and species. Only one species, soft maple, showed a lumber-recovery value increase of as much as 2 percent per year. Five other species—ash, basswood, beech, hickory, and hard maple—increased in

lumber-recovery value between 1 and 2 percent per year for one or more log grades. All other species studied showed increases of less than 1 percent per year, and decreases were recorded for some log grades in three of the more prevalent species—hard maple, red oak, and white oak.

As an example of what these small increases in value can mean, the estimate of combined increase in recovery value between 1955 and 1964 for the three most predominant West Virginia Appalachian lumber species groups—red oak, white oak, and yellow-poplar—amounted to only 1.56 percent or $1.95 per thousand board feet. (The methods used to compute these values are shown in tables 4 and 5, in the Appendix.) These three lumber species groups represented almost 70 percent of the hardwood timber volume harvested in 1960. [4] This means that in West Virginia approximately seven-tenths of the total volume of hardwood lumber manufactured showed an average value increase of less than 20 cents per thousand board feet per year over the last 10 years.

The average lumber-recovery values for 11 principal Appalachian hardwood species by log grades for 1955 and 1964 are shown in table 2. This table also shows the percentage of changes in lumber-recovery values between 1955 and 1964, based on the 1955 values, for 11 species, by log grade.

The range in lumber-recovery values for grade 1 logs in 1964 varied from $90.37 for hickory to $201.18 for cherry per thousand board feet. The predominant Appalachian species, red oak, white oak, and yellow-poplar, had lumber-recovery values of $135.00, $145.72, and $132.77 per thousand board feet, respectively. These values were the third, fourth, and fifth lowest lumber-recovery values of all species evaluated.

Six of the 11 species studied had lumber-recovery values for 1964 below $67 per thousand board feet for grade 3 logs. Of these six, red oak and white oak had lumber-recovery values of $64.68 and $65.63 per thousand board feet, respec-

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[4] Ferguson, Roland H. THE TIMBER RESOURCES OF WEST VIRGINIA. U.S. Forest Serv. NE. Forest Exp. Sta., Resource Bull. NE-2, 121 pp., illus. 1964.

Table 2.—Average lumber-recovery values based on log grades for the different hardwood species and log grades in the Appalachian Region during 1955 and 1964, and the percentage of change between these years

(In dollars per thousand board feet)

Species groups	1955 Lumber-recovery value			1964 Lumber-recovery value			Percent change in recovery value between 1955 and 1964		
	Log grade 1	Log grade 2	Log grade 3	Log grade 1	Log grade 2	Log grade 3	Log grade 1	Log grade 2	Log grade 3
Ash	$132.59	$101.80	$ 75.08	$147.97	$110.70	$ 78.60	+11.60	+ 8.74	+ 4.69
Basswood	125.66	99.66	79.56	142.31	110.35	85.39	+13.25	+10.73	+ 7.34
Beech	97.56	79.23	58.79	107.82	87.01	62.98	+10.52	+ 9.82	+ 7.13
Birch	171.41	109.79	64.37	181.59	115.86	66.42	+ 5.94	+ 5.53	+ 3.18
Cherry	192.50	145.08	103.41	201.18	149.80	103.54	+ 4.51	+ 3.25	+ .13
Hickory	77.52	59.41	45.58	90.37	68.89	49.00	+16.58	+15.96	+ 7.50
Hard maple	137.98	95.98	64.11	153.75	101.33	62.30	+11.43	+ 5.57	- 2.82
Soft maple	118.72	103.00	75.48	148.86	130.39	88.83	+25.39	+26.59	+17.69
Red oak	129.74	92.67	67.88	135.00	92.12	64.68	+ 4.05	- .59	- 4.71
White oak	141.33	95.21	70.08	145.72	91.53	65.63	+ 3.11	- 3.87	- 6.35
Yellow-poplar	127.66	98.36	74.50	132.77	104.94	80.42	+ 4.00	+ 6.69	+ 7.95

tively. These values represent decreases of 4.71 and 6.35 percent respectively, from the 1955 values.

Could these composite changes in product values have been predicted if only the trends in lumber prices had been known?

LUMBER PRICE TRENDS

The trends in lumber prices certainly reflect to some degree what is happening to the value of lumber in a log because the lumber-recovery value is determined from these prices.

No. 1 Common-and-Better lumber prices for ash, basswood, beech, and hard maple increased approximately 10 percent. Soft maple prices increased over 20 percent for No. 1 Common-and-Better. Birch, cherry, hickory, red oak, and white oak prices increased about 5 to 10 percent for No. 1 Common-and-Better; and No. 1 Common hickory prices went up 36 percent; No. 1 Common red oak prices remained the same; and No. 1 Common white oak prices decreased 7.5 percent. Yellow-poplar Saps-and-Better prices showed no change, but the No. 1 Common price rose about 5 percent.

From these price trends for No. 1 Common-and-Better lumber, one might expect substantial increases in lumber-recovery values. And, in general, substantial increases did occur in grade 1 logs of the different species.

Prices of the lower grades of lumber increased very little between 1955 and 1964. Most species registered either a lack of change or a substantial decrease. For example, prices of No. 2 Common lumber of cherry, hickory, hard maple, red oak, and white oak decreased 3 to 9 percent and price of No. 2 Common ash did not change. The price of No. 3A Common lumber declined from 7 to 11 percent for three of the major species—hard maple, red oak, and white oak. From the amount of price decline associated with the lower lumber grades, it would be assumed that the product values for grade 3 logs would also be low; and this was generally found to be so.

Analyses of the different lumber-grade price curves (figs. 12 to 22) indicate the change, or lack of change, that occurs

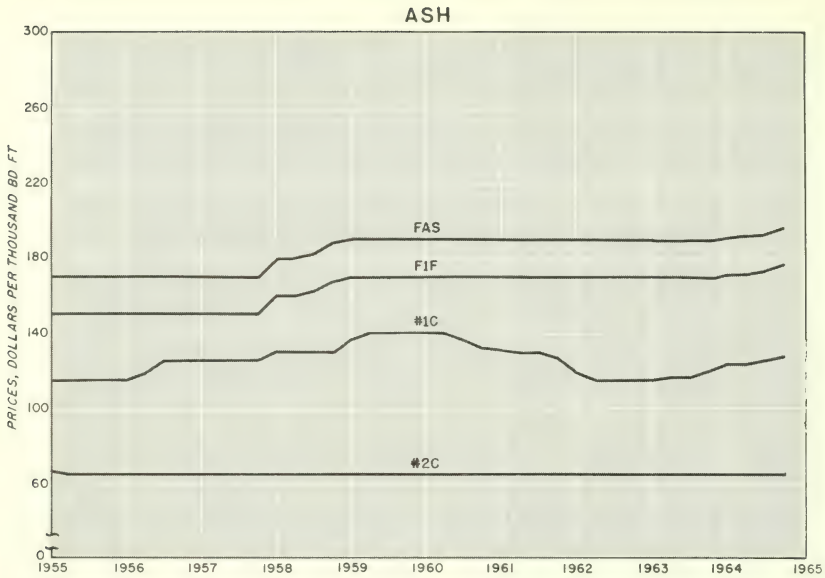

Figure 12.—Trends in prices for 4/4 ash lumber in the Appalachian region, by lumber grades, 1955-64.

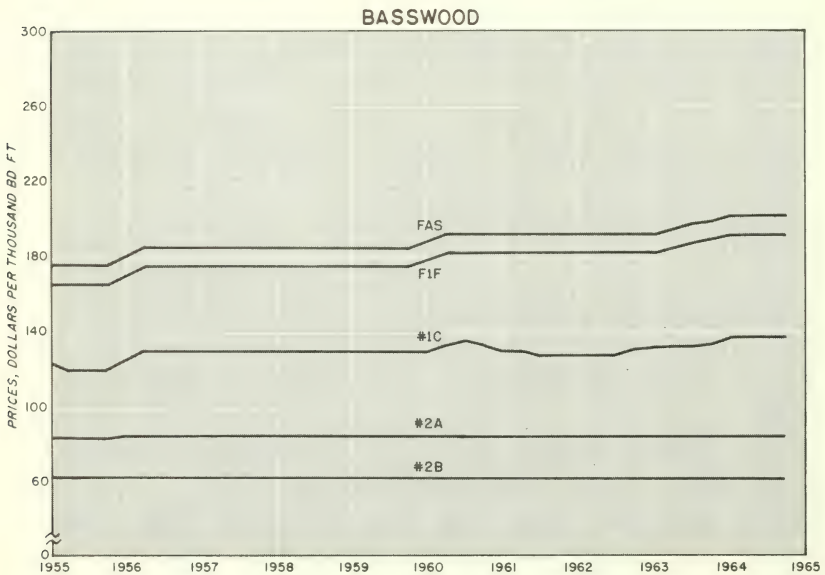

Figure 13.—Trends in prices for 4/4 basswood lumber in the Appalachian region, by lumber grades, 1955-64.

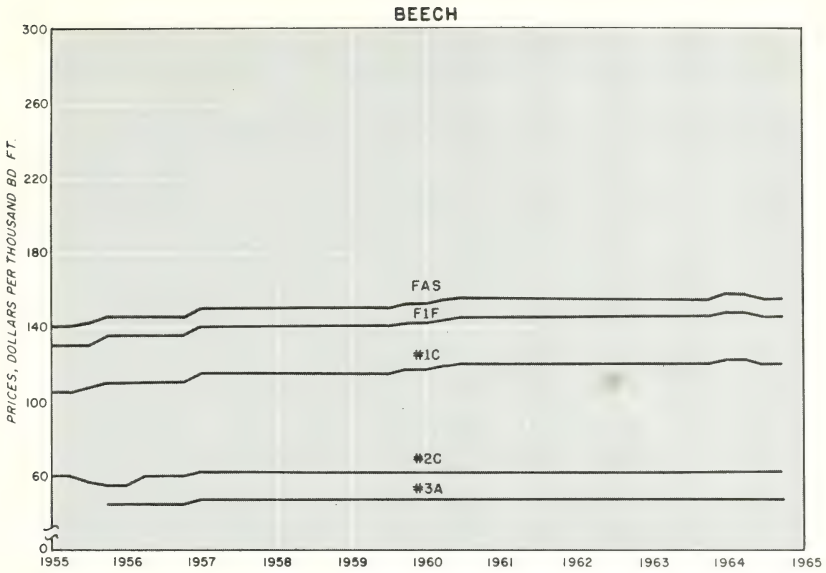

Figure 14.—Trends in prices for 4/4 beech lumber in the Appalachian region, by lumber grades, 1955-64.

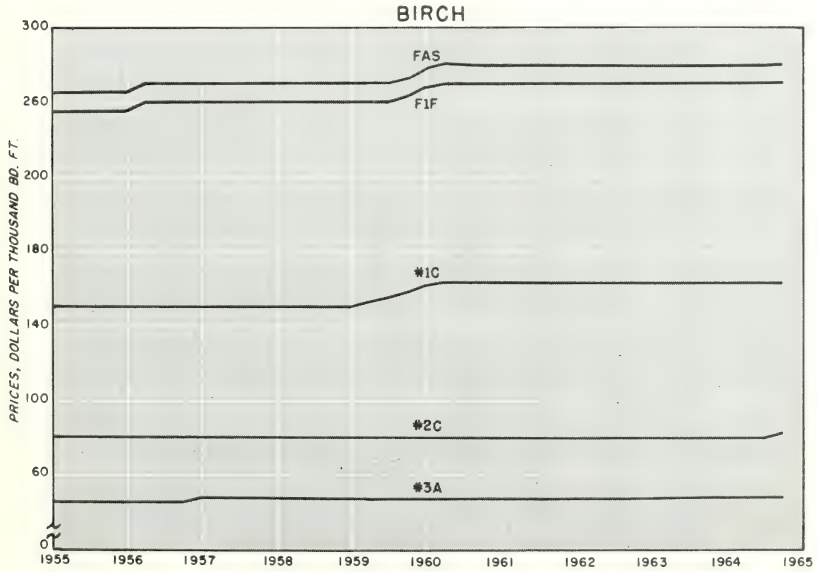

Figure 15.—Trends in prices for 4/4 birch lumber in the Appalachian region, by lumber grades, 1955-64.

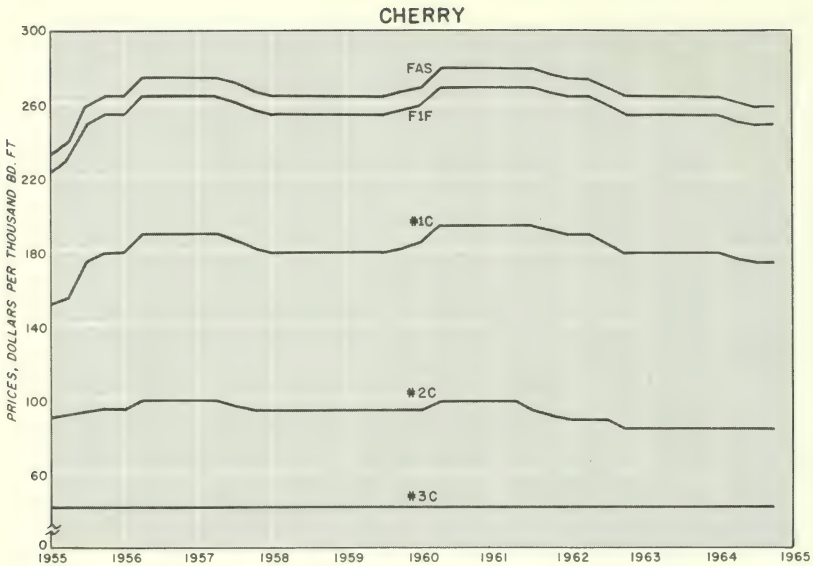

Figure 16.—Trends in prices for 4/4 cherry lumber in the Appalachian region, by lumber grades, 1955-64.

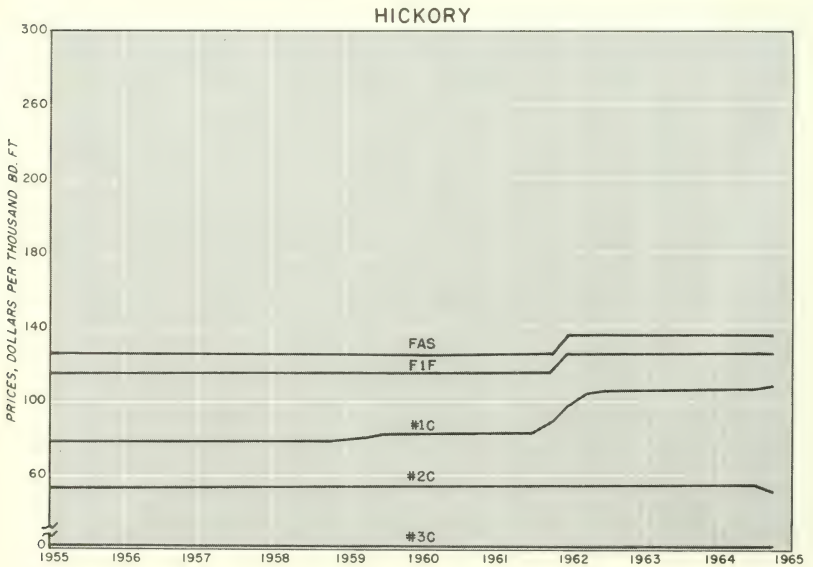

Figure 17.—Trends in prices for 4/4 hickory lumber in the Appalachian region, by lumber grades, 1955-64.

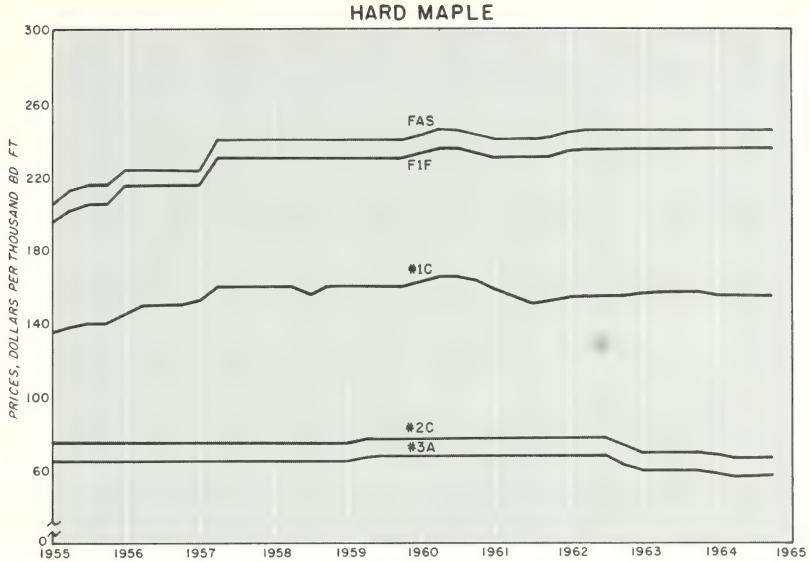

Figure 18.—Trends in prices for 4/4 hard maple lumber in the Appalachian region, by lumber grades, 1955-64.

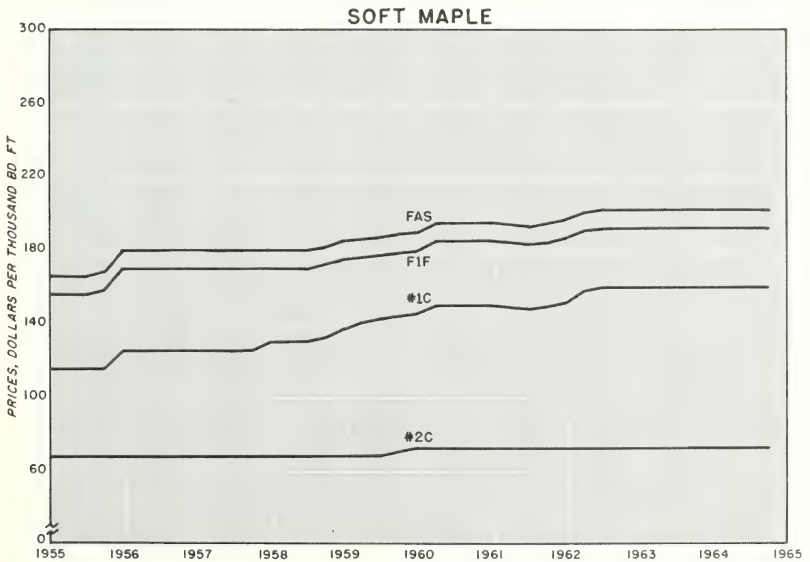

Figure 19.—Trends in prices for 4/4 soft maple lumber in the Appalachian region, by lumber grades, 1955-64.

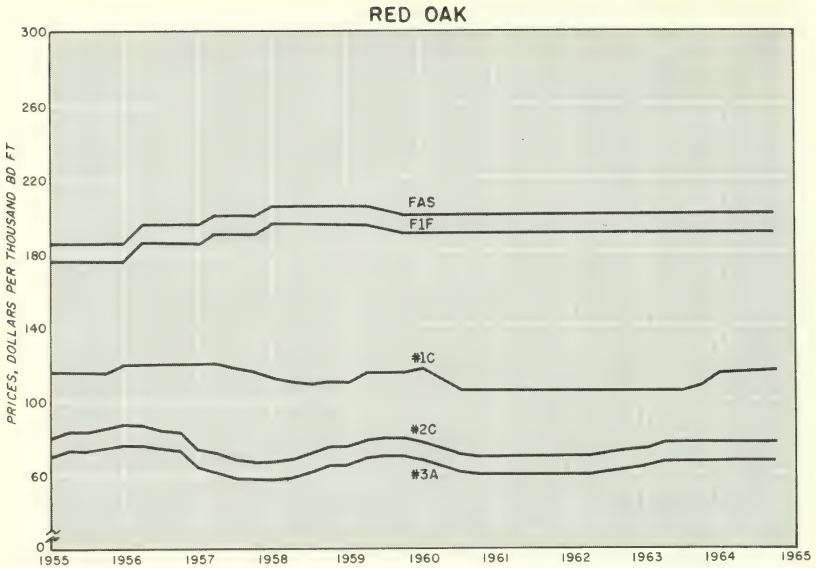

Figure 20.—Trends in prices for 4/4 red oak lumber in the Appalachian region, by lumber grades, 1955-64.

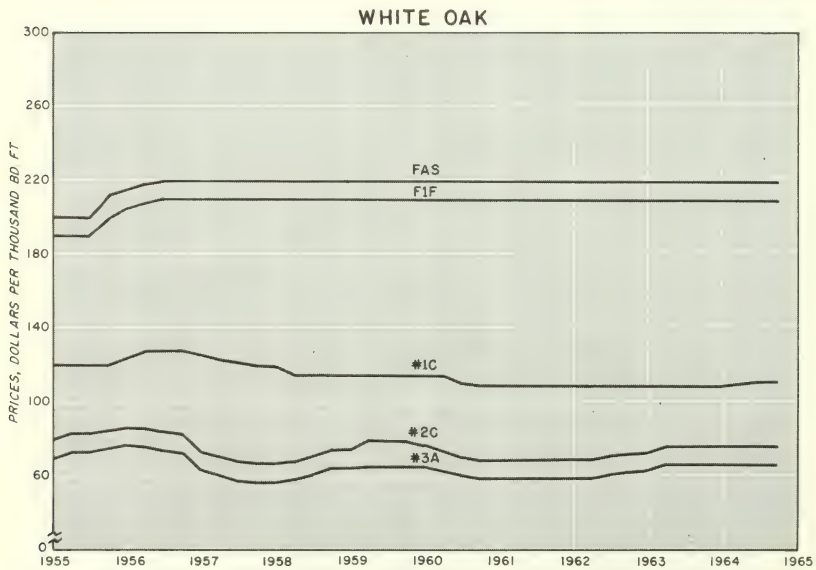

Figure 21.—Trends in prices for 4/4 white oak lumber in the Appalachian region, by lumber grades, 1955-64.

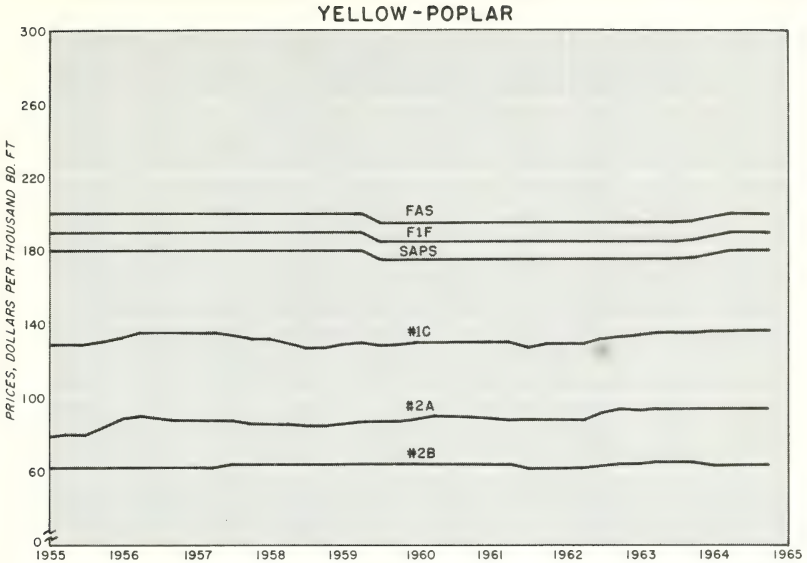

Figure 22.—Trends in prices for 4/4 yellow-poplar lumber in the Appalachian region, by lumber grades, 1955-64.

in one grade with respect to other grades in the same species or similar species. An example is the change in price of No. 1 Common ash and hickory with respect to the prices of the other lumber grades for these species (figs. 12 and 17).

Average quarterly lumber-grade prices based on first-week-of-the-month price quotations in the *Hardwood Market Report* for each species are presented in the Appendix, tables 6 to 16. These represent the actual prices used to plot the lumber price-trend curves in figures 12 to 22.

The average 1955 and 1964 lumber prices for the different Appalachian hardwood species by grades are presented in table 3. The percentage of change in lumber-grade prices between 1955 and 1964 is also shown. The figures in this table represent quantitative values as to the price changes that occurred between the end years of the decade studied.

Table 3.—Average quoted prices for different hardwood species and grades of lumber in the Appalachian Region during 1955 and 1964, and the percentage of change between these years.

(In dollars per thousand board feet)

Species groups	Lumber grades	Average 1955 price	Average 1964 price	Percent change
Ash	FAS	$170	$193	+13.5
	F1F	160	183	+14.4
	# -1C	115	125	+ 8.7
	# -2C	65	65	0
Birch	FAS	265	280	+ 5.7
	F1F	255	270	+ 5.9
	# -1C	150	163	+ 8.7
	# -2C	80	81	+ 1.2
Hard maple	FAS	212	245	+15.6
	F1F	202	235	+16.3
	# -1C	138	155	+12.3
	# -2C	75	68	- 9.3
	# -3A	65	58	- 10.8
White oak-plain	FAS	203	220	+ 8.4
	F1F	192	210	+ 9.4
	# -1C	120	111	- 7.5
	# -2C	83	77	- 7.2
	# -3A	73	67	- 8.2
Basswood	FAS	175	202	+15.4
	F1F	165	192	+16.4
	# -1C	120	137	+14.2
	# -2A	83	85	+ 2.4
	# -2B	62	62	0
Cherry	FAS	250	262	+ 4.8
	F1F	240	253	+ 5.0
	# -1C	166	177	+ 6.6
	# -2C	93	85	- 8.7
	# -3C	42	42	0

Continued

Table 3, Continued.

Species groups	Lumber grades	Average 1955 price	Average 1964 price	Percent change
Soft maple	FAS	166	202	+21.7
	F1F	156	192	+23.1
	# -1C	116	160	+37.9
	# -2C	67	72	+ 7.5
Yellow-poplar	FAS	200	200	0
	F1F	190	190	0
	Saps	180	180	0
	# -1C	129	136	+ 5.4
	# -2A	81	94	+16.0
	# -2B	62	64	+ 3.2
Beech	FAS	142	156	+ 9.9
	F1F	131	146	+11.4
	# -1C	107	121	+13.1
	# -2C	58	62	+ 6.9
	# -3A	45	47	+ 4.4
Hickory	FAS	125	136	+ 8.8
	F1F	115	126	+ 9.6
	# -1C	78	106	+35.9
	# -2C	53	51	- 3.8
Red oak-plain	FAS	185	200	+ 8.1
	F1F	175	190	+ 9.6
	# -1C	115	115	0
	# -2C	83	77	- 7.2
	# -3A	73	67	- 8.2

LUMBER PRICES VS. LUMBER-RECOVERY VALUES

Trends in lumber prices do provide an indication of the corresponding trends in lumber-recovery values, but it is only an indication of the direction of the change and not of the magnitude unless the change is unusually large. As noted previously, a single grade of lumber represents only a proportion of the lumber sawed from any sawlog, and this proportion increases or decreases with the quality or grade of the log. Consequently price changes for one or a few lumber grades cannot possibly provide a complete picture of how the value of all the lumber in a log has been affected.

Logically, price changes in the upper grades of lumber affect log-grade 1 much more than they do log-grade 3 because these upper lumber grades represent a greater portion of grade 1 logs. For example, First-and-Seconds and Selects in upland white oak represent about 46 percent of an average grade 1 log and less than 2 percent of an average grade 3 log. Therefore, a $10 rise in the price of First-and-Seconds and Selects would increase the product value of grade 1 logs by $4.60 and that of grade 3 by only 20 cents per thousand board feet, or 23 times as much for grade 1 as for grade 3 logs.

The reverse is also true to some extent. Changes in the prices for the lower grades of lumber have a greater effect on recovery value of log grade 3 than they do on log grade 1. However, the effect is smaller because of the smaller difference between the proportions of these lumber grades represented in the two grades of logs.

CONCLUSIONS

In general, the fluctuations in prices for hardwood lumber in the Appalachian Region have resulted in only a slight increase in the overall market value of hardwood lumber produced during the past decade.

Although some species and log grades within species had a substantial increase in lumber-recovery value, the proportion of the total volume harvested that these represent is

small. The majority of the lumber grades that increased in price were the higher grades; consequently, this caused the largest increase in lumber-recovery value to be associated with logs of grade 1 quality. In some cases, specifically in the oaks, log-grade 1 was the only log grade within the species that showed an increase in lumber-recovery value between 1955 and 1964. Oak of log grades 2 and 3 decreased in product value. These oak species groups represented approximately one-half the total volume of hardwoods harvested in the Region.

Yet during this same period, lumber-production costs continued to spiral upward. The cost of sawmill equipment alone increased almost 50 percent between 1955 and 1964.[5] Although many Appalachian hardwood sawmills increased their operational efficiency through automation and other improvements, the profit margins remained critical.

Because of the low profit margins in the sawmill industry today, the sawmill owner must keep a watchful eye on his gross income and the costs of operation. This means not only watching individual lumber prices, but also determining the effect that changes in lumber prices have on lumber-recovery values for particular species. Just as the price of an individual lumber grade will not provide the entire picture on the recovery value for a species, neither will the lumber-recovery value of an individual species give the complete picture of gross income. Both must be weighted according to the proportion of the whole that they represent. This is why large increases in prices for one or two lumber grades of a minor species, such as hackberry, have a negligible effect on gross income.

Lumber-recovery values are important because they can provide more than just information on gross income. They can also be used in predicting sawmill profits, in determining economic sawlog and stumpage purchase prices, and in evaluating sawmill conversion practices.[6]

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[5] Sarles, R.L. TEN-YEAR CHANGES IN SELECTED LOGGING AND SAWMILLING COST. S. Lumberman 210 (2620): 28-30. 1965.

[6] Martens, D.G. LOG GRADES—A KEY TO PREDICTING SAWMILL PROFITS. S. Lumberman 210 (2612): 29-34. 1965.

Although many sawmills could be classified as non-profit-making organizations, they were not meant to be that way: most of them are in business to make money. And surely the most efficient and effective management would require a good knowledge of all the factors that affect the overall market value and gross income derived from the major product—hardwood lumber.

■

APPENDIX

Table 4.—Computation of composite percent change in red oak, white oak, and yellow-poplar log-recovery values in West Virginia between 1955 and 1964

Species	Log grade	Species in log grade [1]	Change by log grade [2]	Change in recovery value by species [3]	Species total volume cut [4]	Change in recovery value
		Percent				*Weighted percent*
Red oak	1	46.5	4.05	--	--	--
	2	38.1	- .59	--	--	--
	3	13.5	-4.71	--	--	--
Total		--	--	1.02	36.4	0.37
White oak	1	60.1	3.11	--	--	--
	2	23.1	-3.87	--	--	--
	3	15.7	-6.35	--	--	--
Total		--	--	0.02	12.1	-0.002
Yellow poplar	1	30.0	4.00	--	--	--
	2	47.9	6.69	--	--	--
	3	21.7	7.95	--	--	--
Total		--	--	6.13	19.4	1.19
Composite percentage change in recovery value			--	--	--	1.56

[1] Average found for mill-run sawlogs in several sawmills in West Virginia.

[2] Values taken from table 2.

[3] Product of percent ot species in log grade times percent change by log grade and summed.

[4] Ferguson, *op. cit.*, p. 52. Values calculated from table 23, assuming red oaks to represent 75 percent of select and other red and white oaks cut.

Table 5.—Computation of composite change in monetary value of red oak, white oak, and yellow-poplar log recovery values in West Virginia 1955 and 1964

Species	Log grade	Value change [1]	Log grade as percent of species [2]	Change in value for species [3]	Species as percent of total cut [4]	Weighted monetary change in recovery value
		Thousand board feet	*Percent*	*Thousand board feet*	*Percent*	
Red oak	1	5.26	46.5	--	--	--
	2	- .55	38.1	--	--	--
	3	-3.20	13.5	--	--	--
Total				1.80	36.4	$0.66
White oak	1	4.39	60.1	--	--	--
	2	-3.68	23.1	--	--	--
	3	-4.45	15.7	--	--	--
Total				1.09	12.1	0.13
Yellow-poplar	1	5.11	30.0	--	--	--
	2	6.58	47.9	--	--	--
	3	5.92	21.7	--	--	--
Total				5.97	19.4	1.16
Total composite change in recovery value			--	--	--	$1.95

[1] Values taken as differences between 1955 and 1964 log-recovery values appearing in table 2.

[2] Average found for mill-run sawlogs in several sawmills in West Virginia.

[3] Product of value change times log grade as percent of species and summed.

[4] Ferguson, *op. cit.*, p. 52. Values calculated from table 23, assuming red oaks to represent 75 percent of select and other red and white oaks cut.

Table 6.—Average quarterly prices for 4/4 Appalachian ash, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$170	$170	$170	$180	$190	$190	$190	$190	$190	$191
	2	170	170	170	180	190	190	190	190	190	192
	3	170	170	170	182	190	190	190	190	190	193
	4	170	170	170	188	190	190	190	190	190	197
First 1 Face	1	160	160	160	170	180	180	180	180	180	181
	2	160	160	160	170	180	180	180	180	180	182
	3	160	160	160	172	180	180	180	180	180	183
	4	160	160	160	178	180	180	180	180	180	187
No. 1 Common	1	115	115	125	130	137	140	131	119	115	124
	2	115	118	125	130	140	140	130	115	117	124
	3	115	125	125	130	140	137	130	115	117	125
	4	115	125	125	130	140	132	127	115	120	127
No. 2 Common	1	65	65	65	65	65	65	65	65	65	65
	2	65	65	65	65	65	65	65	65	65	65
	3	65	65	65	65	65	65	65	65	65	65
	4	65	65	65	65	65	65	65	65	65	65

Computed from first-week-of-the month publications of the *Hardwood Market Report. Appalachian Section.* Quoted prices represent estimates of current FOB Appalachian mill-point average market prices on sales to consuming trade on band-sawed Appalachian hard woods in carload quantities, random widths and lengths, rough, air-dried and grade in accordance with National Hardwood Lumber Association rules of inspection.

Table 7.—Average quarterly prices for 4/4 Appalachian basswood, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$175	$180	$185	$185	$185	$188	$192	$192	$192	$202
	2	175	185	185	185	185	192	192	192	195	202
	3	175	185	185	185	185	192	192	192	197	202
	4	175	185	185	185	185	192	192	192	199	202
First 1 Face	1	165	170	175	175	175	178	182	182	182	192
	2	165	175	175	175	175	182	182	182	185	192
	3	165	175	175	175	175	182	182	182	187	192
	4	165	175	175	175	175	182	182	182	189	192
No. 1 Common	1	122	125	130	130	130	130	130	128	132	137
	2	120	130	130	130	130	133	130	128	132	137
	3	120	130	130	130	130	135	128	128	132	137
	4	120	130	130	130	130	133	128	131	133	137
No. 2A Common	1	83	84	85	85	85	85	85	85	85	85
	2	83	85	85	85	85	85	85	85	85	85
	3	83	85	85	85	85	85	85	85	85	85
	4	83	85	85	85	85	85	85	85	85	86
No. 2B Common	1	62	62	62	62	62	62	62	62	62	62
	2	62	62	62	62	62	62	62	62	62	62
	3	62	62	62	62	62	62	62	62	62	62
	4	62	62	62	62	62	62	62	62	62	62

Table 8.—Average quarterly prices for 4/4 Appalachian beech, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$140	$145	$150	$150	$150	$152	$155	$155	$155	$157
	2	140	145	150	150	150	154	155	155	155	157
	3	142	145	150	150	150	155	155	155	155	155
	4	145	145	150	150	152	155	155	155	155	155
First 1 Face	1	130	135	140	140	140	142	145	145	145	147
	2	130	135	140	140	140	144	145	145	145	147
	3	130	135	140	140	140	145	145	145	145	145
	4	135	135	140	140	142	145	145	145	145	145
No. 1 Common	1	105	110	115	115	115	117	120	120	120	122
	2	105	110	115	115	115	119	120	120	120	122
	3	107	110	115	115	115	120	120	120	120	120
	4	110	110	115	115	117	120	120	120	120	120
No. 2 Common	1	60	55	62	62	62	62	62	62	62	62
	2	60	60	62	62	62	62	62	62	62	62
	3	57	60	62	62	62	62	62	62	62	62
	4	55	60	62	62	62	62	62	62	62	62
No. 3A Common	1	--	45	47	47	47	47	47	47	47	47
	2	--	45	47	47	47	47	47	47	47	47
	3	--	45	47	47	47	47	47	47	47	47
	4	45	45	47	47	47	47	47	47	47	47

Table 9.—Average quarterly prices for 4/4 Appalachian birch, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$265	$265	$270	$270	$270	$278	$280	$280	$280	$280
	2	265	270	270	270	270	280	280	280	280	280
	3	265	270	270	270	270	280	280	280	280	280
	4	265	270	270	270	273	280	280	280	280	280
First 1 Face	1	255	255	260	260	260	268	270	270	270	270
	2	255	260	260	260	260	270	270	270	270	270
	3	255	260	260	260	260	270	270	270	270	270
	4	255	260	260	260	263	270	270	270	270	270
No. 1 Common	1	150	150	150	150	150	162	163	163	163	163
	2	150	150	150	150	153	163	163	163	163	163
	3	150	150	150	150	155	163	163	163	163	163
	4	150	150	150	150	158	163	163	163	163	163
No. 2 Common	1	80	80	80	80	80	80	80	80	80	80
	2	80	80	80	80	80	80	80	80	80	80
	3	80	80	80	80	80	80	80	80	80	80
	4	80	80	80	80	80	80	80	80	80	83
No. 3A Common	1	45	45	47	47	47	47	47	47	47	47
	2	45	45	47	47	47	47	47	47	47	47
	3	45	45	47	47	47	47	47	47	47	47
	4	45	45	47	47	47	47	47	47	47	47

Table 10.—Average quarterly prices for 4/4 Appalachian cherry, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$233	$265	$275	$265	$265	$270	$280	$275	$265	$265
	2	240	275	275	265	265	280	280	275	265	262
	3	260	275	272	265	265	280	280	270	265	260
	4	265	275	267	265	267	280	277	265	265	260
First 1 Face	1	223	255	265	255	255	260	270	265	255	255
	2	230	265	265	255	255	270	270	265	255	252
	3	250	265	262	255	255	270	270	260	255	250
	4	255	265	257	255	257	270	267	255	255	250
No. 1 Common	1	152	180	190	180	180	185	195	190	180	180
	2	155	190	190	180	180	195	195	190	180	177
	3	175	190	187	180	180	195	195	185	180	175
	4	180	190	182	180	182	195	192	180	180	175
No. 2 Common	1	91	95	100	95	95	95	100	90	85	85
	2	92	100	100	95	95	100	100	90	85	85
	3	94	100	97	95	95	100	95	90	85	85
	4	95	100	95	95	95	100	92	85	85	85
No. 3 Common	1	42	42	42	42	42	42	42	42	42	42
	2	42	42	42	42	42	42	42	42	42	42
	3	42	42	42	42	42	42	42	42	42	42
	4	42	42	42	42	42	42	42	42	42	42

Table 11.—Average quarterly prices for 4/4 Appalachian hickory, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$125	$125	$125	$125	$125	$125	$125	$135	$135	$135
	2	125	125	125	125	125	125	125	135	135	135
	3	125	125	125	125	125	125	125	135	135	135
	4	125	125	125	125	125	125	125	135	135	137
First 1 Face	1	115	115	115	115	115	115	115	125	125	125
	2	115	115	115	115	115	115	115	125	125	125
	3	115	115	115	115	115	115	115	125	125	125
	4	115	115	115	115	115	115	115	125	125	127
No. 1 Common	1	78	78	78	78	79	82	82	98	105	105
	2	78	78	78	78	80	82	82	104	105	105
	3	78	78	78	78	82	82	82	105	105	105
	4	78	78	78	78	82	82	88	105	105	107
No. 2 Common	1	53	53	53	53	53	53	53	53	53	53
	2	53	53	53	53	53	53	53	53	53	53
	3	53	53	53	53	53	53	53	53	53	53
	4	53	53	53	53	53	53	53	53	53	50
No. 3 Common	1	21	21	21	21	21	21	21	21	21	21
	2	21	21	21	21	21	21	21	21	21	21
	3	21	21	21	21	21	21	21	21	21	21
	4	21	21	21	21	21	21	21	21	21	21

Table 12.—Average quarterly prices for 4/4 Appalachian hard maple, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$205	$225	$225	$240	$240	$242	$240	$244	$245	$245
	2	212	225	240	240	240	245	240	245	245	245
	3	215	225	240	240	240	245	240	245	245	245
	4	215	225	240	240	240	243	241	245	245	245
First 1 Face	1	195	215	215	230	230	232	230	234	235	235
	2	202	215	230	230	230	235	230	235	235	235
	3	205	215	230	230	230	235	230	235	235	235
	4	205	215	230	230	230	233	231	235	235	235
No. 1 Common	1	135	145	152	160	160	162	157	154	156	155
	2	138	150	160	160	160	165	155	155	157	155
	3	140	150	160	160	160	165	150	155	157	155
	4	140	150	160	160	160	163	151	155	157	155
No. 2 Common	1	75	75	75	75	75	78	78	78	70	69
	2	75	75	75	75	77	78	78	78	70	67
	3	75	75	75	75	78	78	78	78	70	67
	4	75	75	75	75	78	78	78	73	70	67
No. 3A Common	1	65	65	65	65	65	68	68	68	60	59
	2	65	65	65	65	67	68	68	68	60	57
	3	65	65	65	65	68	68	68	68	60	57
	4	65	65	65	65	68	68	68	63	60	57

Table 13.—Average quarterly prices for 4/4 Appalachian soft maple, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$165	$180	$180	$180	$185	$190	$195	$197	$202	$202
	2	165	180	180	180	186	195	194	201	202	202
	3	165	180	180	180	187	195	193	202	202	202
	4	168	180	180	182	189	195	194	202	202	202
First 1 Face	1	155	170	170	170	175	180	186	187	192	192
	2	155	170	170	170	176	185	184	191	192	192
	3	155	170	170	170	177	185	183	192	192	192
	4	158	170	170	172	179	185	184	192	192	192
No. 1 Common	1	115	125	125	130	137	145	150	152	160	160
	2	115	125	125	130	141	150	149	159	160	160
	3	115	125	125	130	143	150	148	160	160	160
	4	119	125	125	132	144	150	149	160	160	160
No. 2 Common	1	67	67	67	67	67	72	72	72	72	72
	2	67	67	67	67	67	72	72	72	72	72
	3	67	67	67	67	67	72	72	72	72	72
	4	67	67	67	67	70	72	72	72	72	72

Table 14.—Average quarterly prices for 4/4 Appalachian red oak, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$185	$185	$195	$205	$205	$200	$200	$200	$200	$200
	2	185	195	200	205	205	200	200	200	200	200
	3	185	195	200	205	203	200	200	200	200	200
	4	185	195	200	205	200	200	200	200	200	200
First 1 Face	1	175	175	185	195	195	190	190	190	190	190
	2	175	185	190	195	195	190	190	190	190	190
	3	175	185	190	195	193	190	190	190	190	190
	4	175	185	190	195	190	190	190	190	190	190
No. 1 Common	1	115	119	120	112	110	117	105	105	105	115
	2	115	120	120	110	115	112	105	105	105	115
	3	115	120	116	109	115	106	105	105	105	115
	4	115	120	115	110	116	105	105	105	108	116
No. 2 Common	1	80	86	73	67	75	78	70	70	74	77
	2	83	86	72	68	79	74	70	70	77	77
	3	83	84	68	71	80	71	70	72	77	77
	4	85	83	67	75	80	70	70	73	77	77
No. 3A Common	1	70	76	63	57	65	68	60	60	64	67
	2	73	76	61	58	69	64	60	60	67	67
	3	73	74	58	61	70	61	60	62	67	67
	4	75	73	57	65	60	60	60	63	67	67

Table 15.—Average quarterly prices for 4/4 Appalachian white oak, by lumber grades, 1955-64

Lumber grades	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$200	$215	$220	$220	$220	$220	$220	$220	$220	$220
	2	200	218	220	220	220	200	220	220	220	220
	3	200	220	220	220	220	220	220	220	220	220
	4	212	220	220	220	220	220	220	220	220	220
First 1 Face	1	190	205	210	210	210	210	210	210	210	210
	2	190	208	210	210	210	210	210	210	210	210
	3	190	210	210	210	210	210	210	210	210	210
	4	200	210	210	210	210	210	210	210	210	210
No. 1 Common	1	120	124	126	120	115	115	110	110	110	110
	2	120	128	123	115	115	115	110	110	110	110
	3	120	128	122	115	115	111	110	110	110	112
	4	120	128	120	115	115	110	110	110	110	112
No. 2 Common	1	80	86	73	67	75	78	70	70	74	77
	2	83	86	71	68	80	74	70	70	77	77
	3	83	84	68	71	80	71	70	72	77	77
	4	85	83	67	75	80	70	70	73	77	77
No. 3A Common	1	70	76	63	57	65	66	60	60	64	67
	2	73	76	61	58	66	64	60	60	67	67
	3	73	74	58	61	66	61	60	62	67	67
	4	75	73	57	65	66	60	60	63	67	67

Table 16.—Average quarterly prices for 4/4 Appalachian yellow-poplar, by lumber grades, 1955-64

Lumber	Quarter	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
First-and-Seconds	1	$200	$200	$200	$200	$200	$195	$195	$195	$195	$198
	2	200	200	200	200	200	195	195	195	195	200
	3	200	200	200	200	195	195	195	195	195	200
	4	200	200	200	200	195	195	195	195	195	200
First 1 Face	1	180	180	180	180	180	175	175	175	175	178
	2	180	180	180	180	180	175	175	175	175	180
	3	180	180	180	180	175	175	175	175	175	180
	4	180	180	180	180	175	175	175	175	176	180
No. 1 Common	1	129	132	135	132	129	130	130	129	134	136
	2	129	135	135	130	130	130	130	129	135	136
	3	129	135	134	127	129	130	127	132	135	136
	4	130	135	132	127	129	130	129	133	135	136
No. 2A Common	1	79	89	88	86	86	88	89	88	93	94
	2	80	90	88	86	87	90	88	88	94	94
	3	80	89	87	85	87	90	88	92	94	94
	4	84	88	86	85	87	90	88	93	94	94
No. 2B Common	1	62	62	62	64	64	64	64	62	65	63
	2	62	62	62	64	64	64	64	62	65	63
	3	62	62	64	64	64	64	62	63	65	63
	4	62	62	64	64	64	64	62	64	65	63

PLASTIC TUBING FOR COLLECTING MAPLE SAP:

A Comparison of Suspended Vented and Unvented Installations

by Barton M. Blum

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

PLASTIC TUBING FOR COLLECTING MAPLE SAP:

A Comparison of Suspended Vented and Unvented Installations

■

The Author

BARTON M. BLUM, associate silviculturist, joined the Northeastern Forest Experiment Station in February 1957 shortly after earning his Master's degree in forestry from Yale University. He had earned his Bachelor's degree at Rutgers University in 1954, and served about a year with the U.S. Air Force in 1954 and 1955. Mr. Blum has worked 3 years for the Station on forest surveys; 5 years on the Silviculture project, then at Laconia, N.H.; and about 2 years on the maple sap production project at Burlington, Vt.

THE QUESTION OF VENTING

PLASTIC TUBING for sap collection has been acclaimed as a major factor in modernizing the 300-year-old maple sap industry. Tubing reduces the labor costs involved in sap collection, keeps the sap cleaner, reduces loss due to spillage, and is relatively easy to install. Yet in spite of these advantages, tubing is used by only 9 percent of the maple sap producers.[1]

One of the primary reasons why tubing does not enjoy more widespread use among maple producers today is that the initial installations did not operate efficiently. When tubing first appeared on the scene, maple sap was thought to issue from the tree at considerable pressure, and many of the first installations were patterned after high-pressure water systems.[2] These installations were unvented (closed to air) in the anticipation that tree pressure would be sufficient to force sap through the lines.

It was soon found that the anticipated sap pressure was not adequate, and that in reality sap issues from the maple tree over a range of pressures. Some tubing advocates then designed their installations for gravity flow, and vented the installation at each spout. Since the completely vented installation allowed sap to flow under a variety of adverse field conditions, the vent system was adopted by many producers.

However, a significant number of producers were able to make unvented installations work efficiently and continued to use them. This indicated that some of the trouble with these initial unvented installations must have stemmed from layout and design problems.

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[1] Cowen, William. Address given at the Geauga County Institute of Forestry and Maple Syrup Production and Marketing in Burton, Ohio, January 1966.

[2] Willits, C. O. MAPLE SYRUP PRODUCERS MANUAL. U. S. Dep. Agr., Agr. Handbook 134, 112 pp. 1965.

But the two methods of installation were never formally compared on the basis of sap yield until Laing *et. al.*[3] conducted a small-scale comparison of the two, using the sap yield from 40 trees located in northern Vermont. The results of this study indicated that the unvented system outyielded the vented system by about 55 percent.

The subject of venting nevertheless remained somewhat controversial, and most tubing users continued to vent. Therefore, researchers at the U. S. Forest Service's sugar maple project in Burlington, Vt., designed a large-scale comparison of vented and unvented tubing installations for the 1966 sap season. The objective of this study was to compare sap yields from the two methods of tubing installation and to investigate the factors involved in any observed differences in yield.

THE STUDY

To provide a statistically sound comparison, we suspended tubing in paired vented and unvented installations. The installations were identical in the number of tapholes, position of spouts and drops in relation to exposure, degree of slope, total tubing length, the amount of sag between trees, and other factors (fig. 1). All tubing was 5/16-inch inside diameter, and all fittings were identical for each installation in the pair. The only difference between members of a pair was the treatment—one was vented, and the other was unvented (fig. 2).

For further reduction of experimental error, tapholes were paired 6 inches apart and bored to a controlled depth of 2½ inches, excluding bark. Since there is little lateral translocation of sap, paired tapholes yield independently of one another.[4] Tapholes were placed 4½ feet from the ground except where they were adjusted to maintain adequate slope. Paraformalde-

[3] Laing, F. M., J. W. Marvin, and W. J. Chamberlain. RESULTS AND EVALUATION OF NEW MAPLE TECHNIQUES. Univ. Vt. Agr. Exp. Sta. Misc. Pub. 42. (Prog. Rep. 3), 13 pp. 1964.

[4] Jones, C. H., A. W. Edson, and W. J. Morse, THE MAPLE SAP FLOW. Vt. Agr. Exp. Bull. 103, 184 pp. 1903.

Figure 1.—Tubing installations. Members of a paired replicate were kept as alike as possible in line sag, tubing length, and other factors.

hyde pellets were used in each taphole. Vented and unvented installations were assigned to the tapholes at random.

Differences in yield between vented and unvented tapholes were tested for significance with a "t" test for paired replicates.

To provide a comparison large enough to duplicate commercial conditions, we used 15 replicates. Each replicate included 18 to 20 pairs of tapholes, making a total of 580 individual tapholes in the study. The 18 to 20 individual tapholes receiving the same treatment in a replicate were connected into one tubing system.[5]

The length of tubing used for each member in the paired replicates ranged from 237 to 347 feet and averaged 300 feet. The slope of the lines varied from 14 to 21 percent and averaged about 18 percent, although some pairs had nearly level segments. Vertical drop from the first tree tapped to the col-

[5] Tubing manufacturers recommend that about 20 tapholes be connected in each tubing system when small diameter lines like these are used.

Figure 2.—A taphole pair, typical of those in the paired replicates. Note icicle formed by sap leaking from the vented member of the pair (left).

lection barrel ranged from 17 feet to about 30 feet. No attempt was made to minimize abrupt changes either in the slope or in line direction.

The sugarbush used for the study is densely stocked with about 200 trees per acre; the trees averaged 12 to 14 inches d.b.h. This bush slopes generally northwest and is situated at an altitude of 1,000 feet. It is located in northwestern Vermont in the town of Jericho.

RESULTS AND DISCUSSION

Yield Comparisons

Venting significantly (0.01 level) affected the seasonal yield of sap collected in plastic tubing. From the first week in March to 2 May 1966, the combined yield from the unvented installations on all 15 replicates was 43 percent greater than that from the vented installations (table 1).

Although the unvented system had an average yield for the entire season that was 43 percent greater than that of the vented system, there was considerable variation in the magnitude of this increase from one measurement period to the next. This variation appeared to be related to the volume and rate of flow during the period. In general, fast flows of relatively large volume produced a greater difference in the percent of yield between the two systems. However, yield increases for the unvented installations occurred consistently, even during the extensive period of low-yield, weeping flows between 7 April and 2 May. There was also considerable variation in the size of the yield difference among the 15 paired replicates, a factor that will be discussed in some detail later.

Based on the average yields found in this study, the increase in seasonal yield for an unvented system in a 1,000-taphole operation would be about 2,680 gallons of sap. An increase of this magnitude is economically important, amounting to $134.00 if the sap is sold for $.05 per gallon. This additional yield at

2.5 percent sugar content would make 78 more gallons of syrup—worth $468 at an average of $6 per gallon—for the same outlay of sap collection labor and equipment. And many sugarbushes would have an average sap sugar content of more than 2.5 percent, further increasing the value of the difference in yield. The somewhat cheaper initial equipment costs for an unvented system will also be important in new installations.

We do not know whether this additional yield reflects a reduction of sap from the vented installations or an increase from the unvented installations. However, some information was gathered on this question during the study.

Loss of Sap from Vents

Producers using vented installations often express concern over sap loss from the open vents (fig. 3). This loss usually occurs when sap is forced out of the vents by an obstruction in

Table 1.—Season yields and yield differences for unvented and vented members of the paired replicates, 1966 season

Replicate	Tapholes per member	Yield per taphole		
		Unvented	Vented	Difference
No.	*No.*	*Gallons*	*Gallons*	*Gallons*
1	19	7.60	6.66	0.94
2	20	13.12	5.42	7.70
3	18	9.89	8.57	1.32
4	19	8.68	6.98	1.70
5	19	9.97	7.42	2.55
6	20	10.57	5.59	4.98
7	20	6.53	5.17	1.36
8	19	7.87	5.49	2.38
9	20	8.91	6.67	2.24
10	20	7.74	4.88	2.86
11	19	8.36	6.99	1.37
12	19	7.23	6.03	1.20
13	19	5.64	5.90	—.26
14	20	10.91	6.25	4.66
15	19	10.94	5.80	5.14
Total	290	133.96	93.82	40.14
Average	—	8.93	6.25	2.68

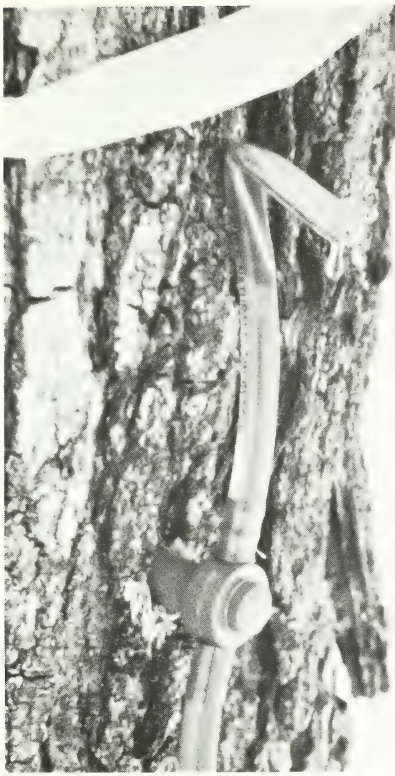

Figure 3.—Sap leaking from a vent. These leaks are caused by obstructions in the line that back up sap. They sometimes form large icicles during cold weather.

the tubing. Obstructions most commonly cited are ice blockages and gas or vapor locks. Vent loss may also occur when too much sap is present in the branch line (this might happen during very heavy flows) or when too many tapholes are put on a line, or when slope is insufficient. Vent loss is particularly noticeable when the weather is very cold, as evidenced by icicles formed where the sap leaves the vent.

Sap loss through the vents was measured for the entire season on the vented members of two paired replicates, numbers 6 and 11 (fig. 4). Both were chosen because they had a number of long spans, shallow slopes in some segments, and a number of sharp changes in direction and slope—all thought to be conducive to vent loss under certain conditions. Actual losses recorded were less than 3 percent of the total seasonal yield of

Figure 4.—Plastic bags were placed over the vents on two replicates to measure sap loss from leaks.

the vented members of the two replicates. Compared with the yield differences between the vented and the unvented members of the replicates, these sap losses were slight (table 2).

In any given year this vent loss could have been either larger or smaller, depending primarily on temperature conditions conducive to ice obstruction during the season. Close observation during the season indicated that vent losses from the other replicates in the study did not differ greatly from those measured on replicates 6 and 11.

Vacuum Relationships

It was apparent that some factor or factors other than vent loss from the vented installations must be involved in the greater yields obtained from the unvented installations. One factor investigated in this study was the presence of vacuum on the unvented lines and its relation to yield increases.

Table 2.—Vent losses from replicates 6 and 11, and the yield increase for the unvented members of these same replicates, 1966 sap season

Replicate	Vent loss per taphole	Yield increase for unvented member per taphole
No.	*Gallons*	*Gallons*
6	0.16	4.98
11	.22	1.37

Table 3.—Vacuum at the uphill end of the closed installations, measured during a moderately heavy flow

Replicate	Vacuum	Replicate	Vacuum
No.	*mm of mercury*	*No.*	*mm of mercury*
1	40	8	20
2	450	9	210
3	20	10	210
4	200	11	250
5	140	12	150
6	470	13	0
7	(1)	14	300
		15	400

[1] Vacuum lost during measurement.

Figure 5.—A drop line distorted by vacuum buildup in the tubing system.

Because of the movement of sap through the tubing, some vacuum was expected to develop in the unvented installations. However, shortly after the first flows occurred it was evident that this vacuum was of considerable magnitude and actually caused tubing distortions on some lines (fig. 5). The possibility of a correlation between vacuum and yield was considered, and steps were taken to measure vacuum at the upper end of each vented installation (table 3). Vacuum readings, taken with a standard vacuum gage, were obtained during a moderately heavy flow for all 15 replicates (fig. 6). The vacuum-forming and -holding capacity of each replicate appeared to be a function of slope, the amount of sap in the tubing at the time of measurement, and the vacuum integrity of the fittings, spouts, and tapholes.

The vacuum readings were plotted against the seasonal yield differences found between the unvented and the vented members of each replicate (fig. 7), and a linear regression line was fitted to these data. The resulting correlation coefficient

of 0.86 was significant at the 0.01 level. Since actual vacuums measured on the installations would vary for any given flow, the prediction equation is not of great practical value.

Attempts to get vacuum readings during weeping flows were mainly unsuccessful. However, on one occasion some relatively low vacuum readings were obtained on about half of the replicates, and these were plotted against corresponding yield differences from this same flow. The resulting regression line was also significant at the 0.01 level and indicates that yield increases are also related to the low vacuum levels associated with very light flows.

Figure 6.—Measuring vacuum with a standard vacuum gage calibrated in mm of mercury.

In view of the strong relationship between vacuum and increased sap yield, and since direct losses from the vented system were small, it appears that the vacuum present on the unvented system draws additional sap from the tree. The mechanism of

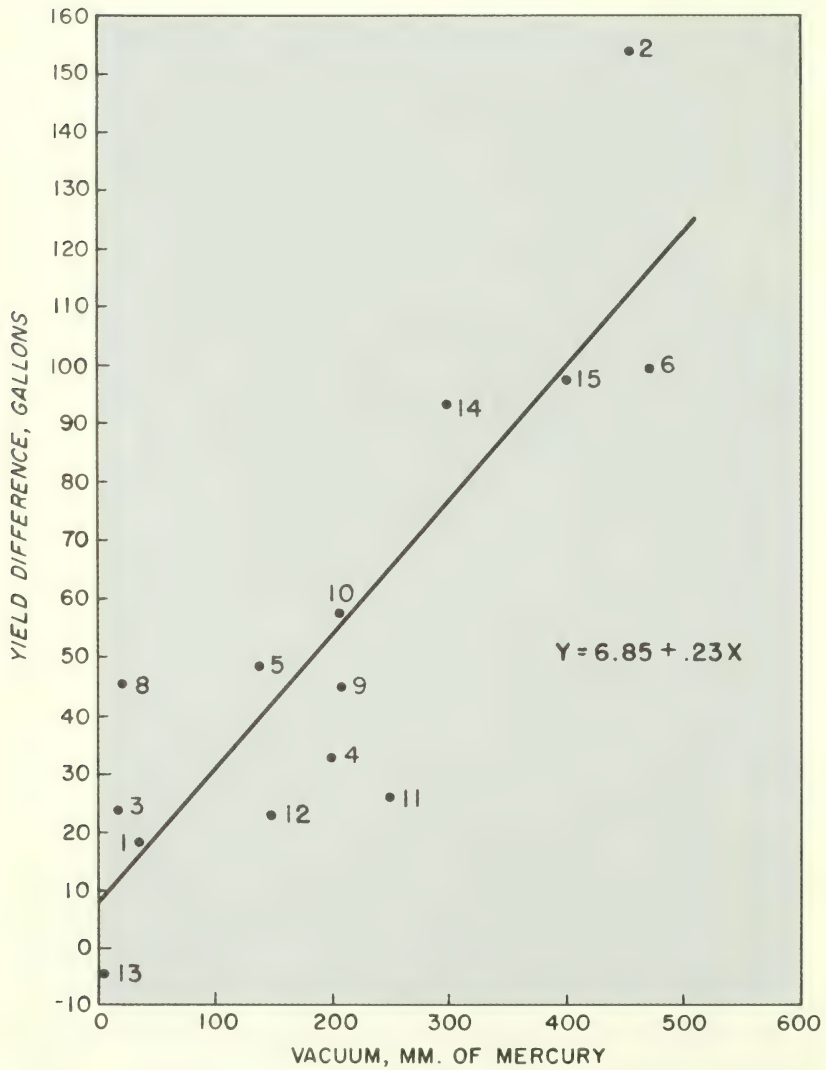

Figure 7.—Relationship between line vacuum and differences in seasonal yield from vented and unvented tubing systems.

this action is unknown. It may be that the vacuum simply prevents a build-up of sap behind the spout, which would restrict flow. Or it may be that the vacuum somehow alters the normal sap translocation processes.

CONCLUSIONS AND RECOMMENDATIONS

This study indicates that higher sap volumes can be obtained from unvented installations. Increases in yield can be expected with certainty only from installations similar to those used in this study and installed where similar conditions of weather and topography prevail. Nevertheless, it is reasonable to assume that yield increases will be obtained from unvented installations over a range of topographic and weather conditions. This likelihood will be studied at a number of locations in the maple region during the spring of 1967.

Coupled with the possibility of greater yields of sap from unvented tubing installations are other advantages: Sap is less likely to be contaminated with micro-organisms in an unvented installation than it is in a vented installation; and in the case of initial installations, costs are somewhat less. Although no particular difficulty was experienced with the suspended installation used in this study, we must caution that a properly working, suspended, unvented system may need tailoring to each different set of field conditions, just as any tubing system does. Since yield increases of the magnitude found in this study are a definite possibility, producers now using vented installations may find it profitable to experiment with sections of unvented tubing under conditions found in their own sugar bushes.

■

FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

SNOOP:

A COMPUTER PROGRAM

For 2- and 3-Dimensional Plotting

by Warren E. Frayer

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JUN 1968
SCI., TECH. & AGR. DIV.

U.S. FOREST SERVICE RESEARCH PAPER NE-91
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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THE NEED FOR SNOOPING

COMPUTER programs for two-dimensional (2D) plotting are numerous, and at least one is available in the library of most computer installations. However, in the process of model-building, researchers often want to examine graphed data for the presence of possible interactions of independent variables. This type of data "snooping" is common; but, to make use of available (canned) program decks, researchers must often resort to separating data into small sets and constructing and comparing several two-dimensional graphs.

To help with this chore, we have developed a computer program called SNOOP.

WHAT SNOOP WILL DO

Program SNOOP allows examination of interactions by extending two-dimensional (2D) graphing procedures to three-dimensional (3D) plotting. A variable hereafter referred to as a plotting character (PC) denotes the third dimension. The PC can assume values from 0 to 9 and is designated by the content of a selected card column in the observation data. The numeric characters that appear on the completed graph are the actual PC values that appear on the cards (a blank results in a PC value of 0).

For example, if volume, diameter, and height are measured on a group of felled trees, the 2D relationship of volume and diameter can be plotted on the same graph and up to 10 values (or classes) of the plotting character (height) can be distinguished. Examination of the graph may then result in selections of appropriate transformations, interaction terms, and/or weights to be applied in regression analysis. This procedure is not necessary for so simple a problem as postulated here, but extension of the possible uses of 3D plotting should be obvious. However, because of its simplicity, a volume-estimation problem is used as an example later.

Two-dimensional plotting is also available to the user of SNOOP. In this case the numeric characters that appear on the completed graph are frequencies of occurrence. The resulting character at any set of coordinates may then be blank (no occurrence), 1 to 9, or 0 (10 or more).

If overplots are attempted, messages (containing the coordinates and, in the case of 3D plotting, the PC values) are printed after the appropriate graph. An attempted overplot would occur when 2 or more observations have identical coordinates for 3D plotting, or 11 or more observations for 2D plotting.

When several dependent (Y) and independent (X) variables are included in one job, a set of fully labelled graphs is made, including each Y-X combination. And, for 3D, a separate set of graphs is made for each PC specified. The program automatically scales the graphs for each variable used. Other flexibility available to the user, barring certain properties given in the section *Program Restrictions,* can be summarized as follows:

> 2D and 3D jobs can be included in the same run in any order. As many jobs as desired may be included in a single run. Observation values can be negative, zero, and positive. Order of the variables on the observation cards is completely flexible.
>
> PC's can be located anywhere on the observation cards. Multiple cards per observation can be used.

WHEN TO USE THE PROGRAM

The major use of program SNOOP is in the model-building stage of an estimation problem. A segment of data can be plotted in various ways, and the graphs can be examined for logical trends in dependent-variable values as responses to changes in the values of independent variables. Models can then be formed for regression analyses with the remaining data.

Consequently the value of the program is easily recognized when the researcher is attempting to explain previously unfamiliar functional relationships between many variables. With only a few variables, many observations, and expectations that limit the possibilities of functional-relationship alternatives, the researcher can go directly to the use of one of the canned regression routines—for example, Furnival[1]—available at any large computer center.

HOW TO USE THE PROGRAM

The program is activated by a control deck supplied by the user. The control deck consists of cards containing the observations and information designating a specific manner in which the observations are to be handled by the program. The following instructions describe the complete control-deck setup (all underlined characters *must* be punched exactly as they appear in the instructions):

Card group	*Number of cards*	*Title*	*Card columns*	*Content*
1	1	Job description	1-2	*2D*—For 2-dimensional plotting.

[1] Furnival, G. M. More on the elusive formula of best fit. Soc. Amer. Foresters Proc. 1964: 201-207.

				3D—For 3-dimensional plotting.
			3-4	Number of Y's (NYS), right adjusted.
			5-6	Number of X's (NXS), right adjusted (does not include PC variables).
			7-8	Number of plotting characters (NPC), right adjusted. Use *00* (or blanks) for 2D.
			9-11	Number of observations (NOBS), right adjusted.
			12	Number of cards per observation (NCARDS). The use of *0* (or blank) will be interpreted as *1*.
			13-72	Alphameric job title to be printed above each graph.
2	1	Format	1	*1*—There is no format continuation card.
				2—The format specification is continued on the format continuation card.
			2	*(*—Left parenthesis.
			3-72	Up to 70 alphameric characters, ending with a right parenthesis, and containing a FORTRAN BCD format[2] (F-specifications), which

[2] Refer to any text on FORTRAN IV for descriptions of BCD formats (F-specifications as used here and E-specifications as used in portions of SNOOP output).

				describes the format of the Y's and X's on the observation cards. The right parenthesis is put on the format continuation card if column 1 of the format card = 2.
3	0 or 1	Format continuation	1-72	Continuation of the format specification described for columns 3-72 of the format card.
4	NYS + NXS	Variable labels	1	*Y*—If the variable is a dependent variable. *X*—If the variable is an independent variable.
			2	Blank.
			3-52	Alphameric label (identifying information) associated with the variable. This group of cards must be arranged in the order that the variables appear on the observation cards.
5	0 if 2D, NPC if 3D	3D plotting characters	1-18	*PLOTTING CHARACTER*
			19	Blank.
			20	Number of the card (of the observation set) on which the PC value is found. The use of *0* (or blank) will be interpreted as *1*.
			21-22	Column number (right-adjusted) in which the

				PC value is found.
			23	Blank.
			24-31	Alphameric label (identifying information) associated with the PC.
6	NOBS xNCARDS	Observations	1-80	One or more cards for each observation as designated by the format cards.
7	1	Job control	1-8	*CONTINUE*—If more than one job is included in the run. Card groups 1-7 are repeated after the job control card. *DONE* (left adjusted) —Designates the end of the last job in the run.

An example of a control deck is shown in the appendix.

PROGRAM RESTRICTIONS

Job restrictions applying both to 2D and 3D plotting are:

$$NYS + NXS \leq 50$$
$$NYS \geq 1$$
$$NXS \geq 1$$
$$2 \leq NOBS \leq 500$$
$$1 \leq NCARDS \leq 9$$

Job restrictions pertaining to 3D plotting only are:

$$(NYS + NXS + NPC) \times NOBS \leq 10{,}000$$
$$1 \leq NPC \leq 10$$

A job restriction pertaining to 2D plotting only is:

$$(NYS + NXS) \times NOBS \leq 10{,}000$$

HOW TO USE THE RESULTS

For the researcher who is developing a regression model, the graphs produced by the program can be a valuable aid in selecting transformations, interaction terms, and variance-stabilizing weights, and in ordering of variables.

As an example, let us examine the sample control deck in Appendix I and the output in Appendix II.

The first page of output consists of summary information pertaining to the entire job. Card groups 1 to 5 of the control deck are printed as well as the values of all the variables in the first observation (the Y's precede the X's in the printout). Because the first job in this example specifies 3D plotting, the values of the plotting characters for the first observation are also included in the summary information.

Now, assume for the moment that expectations of functional relationships involving cubic-foot volume, diameter, and height are vague. The trees plotted in this example could be an initial sample of trees to be measured in the construction of a standard volume table; that is, we want to express cubic volume as a function of both diameter and height, if possible. Consequently, the control deck has been set up to plot a 3D graph of cubic-foot volume as a function of diameter, using 10-foot height class as a plotting character.

The resultant graph shows that volume increases with an increase in diameter, and there is an increase in the slope of the relationship as diameter increases.

Free-hand curves as they would be drawn on the graph for several groups of the 10-foot height classes are shown in figure 1. These can be represented in three dimensions as in figure 2.

Upon close examination — by methods described by Jensen[3] — figure 2 suggests that, for a given height, volume is a function of the square of diameter. Also, for a given diameter, volume

[3] Jensen, C. E. ALGEBRAIC DESCRIPTION OF FORMS IN SPACE. U. S. Forest Serv., Cent. States Forest Exp. Sta. Misc. Pub. 57 pp. Columbus, Ohio. 1964.

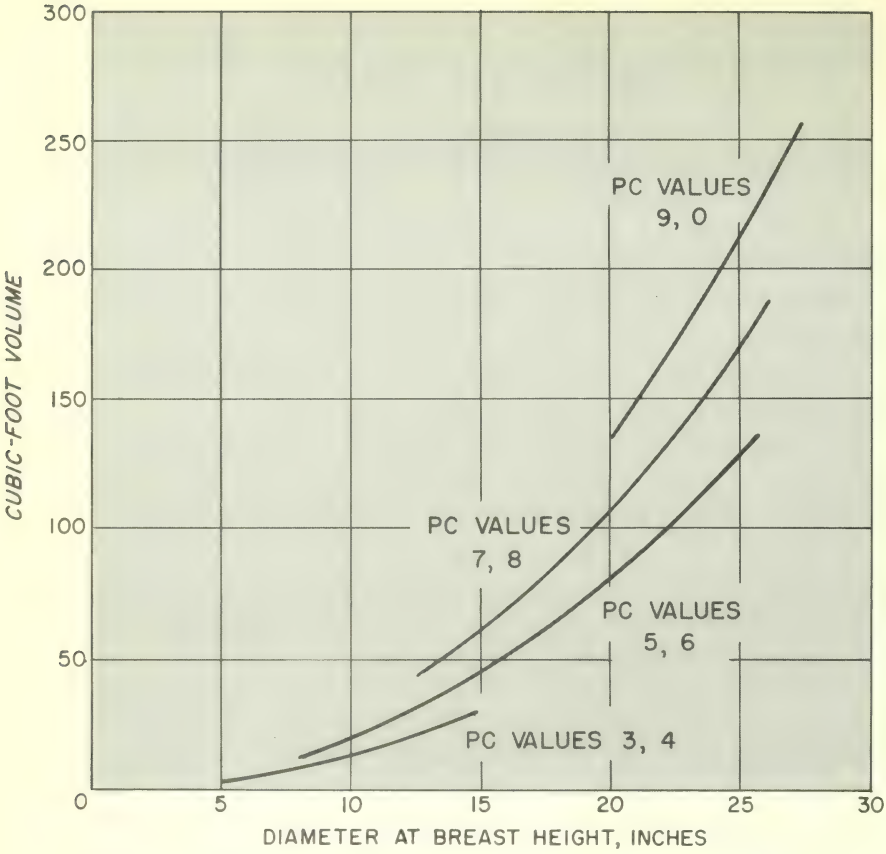


Figure 1.—Hand-fitted curves for four height-class groups.

appears to be a linear function of height. Thus, the interaction term of $[(\text{diameter})^2 \times \text{height}]$ would be an appropriate independent variable for regression analysis. The user might also study the graph further to determine a weighting procedure to stabilize the variance of volume as $[(\text{diameter})^2 \times \text{height}]$ varies.

Following the graph is the printed list of attempted overplots, including their coordinates and PC values. Following the overplots, the printed message CONTINUE signifies that the program is continuing to the next job in the run.

The second job is simply a demonstration of 2D graphing. The same observations were used as in the first job. Two graphs were specified by designating volume as a dependent variable

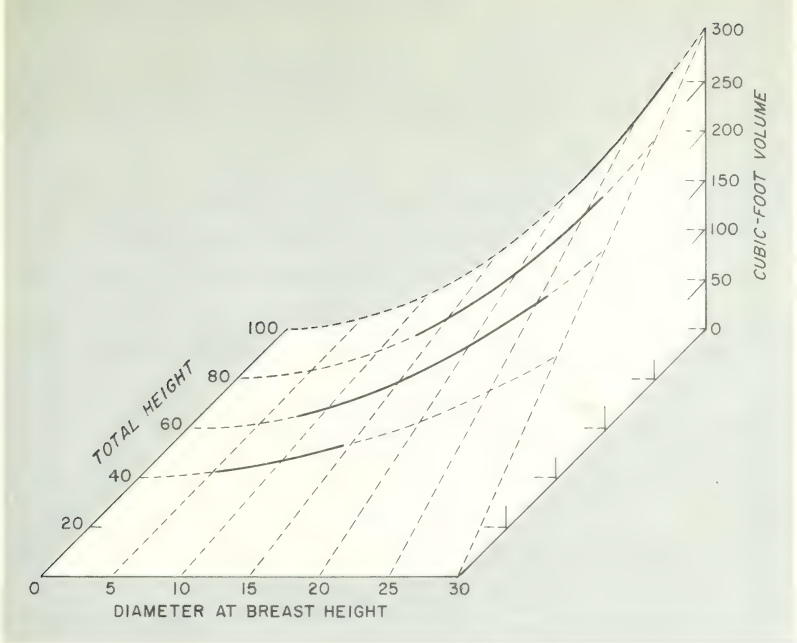


Figure 2.—Cubic-foot volume as a function of the joint distribution of tree diameter at breast height and total tree height.

and diameter and height as independent variables. The reader will note that the numbers printed in the resultant graphs are frequencies of occurrence. There are no overplots, and the printed message DONE signifies that the last job has been run.

INFORMATION FOR PROGRAMMERS

Program SNOOP was thoroughly tested and is operational on an IBM 7040 computer with the IBSYS monitor. The program is written in FORTRAN IV and should run with little or no modification on other computers that accept FORTRAN IV, have a 32K core, and have three tape drives or equivalent input/output devices. The logical tape assignments are:

Unit	*Use*
5	Control-deck input
6	Program output
9	Intermediate operations (scratch tape)

A special subroutine was necessary for backspacing logical unit 5 at the computer installation where this program was developed. A simple BACKSPACE 5 command or its equivalent is all that is necessary at other installations. The two places in the program where this must be done are marked with comments. A general flow diagram of the program is shown in figure 3. And a listing of the program is presented in appendix III.

ERROR MESSAGES

When the user makes an error in preparing the control deck, the program will print a message if the error is such that execution of the program would be illogical or impossible. The program then continues to scan the control deck for additional jobs. The error messages used by the program are:

NYS = XX
NYS MUST BE GREATER THAN 0 AND LESS THAN 50

NXS = XX
NXS MUST BE GREATER THAN 0 AND LESS THAN 50

NPC = XX
NPC MUST BE BLANK OR 0

NPC = XX
NPC MUST BE GREATER THAN 0 AND LESS THAN 11

NOBS = XXX
NOBS MUST BE GREATER THAN 1 AND LESS THAN 501

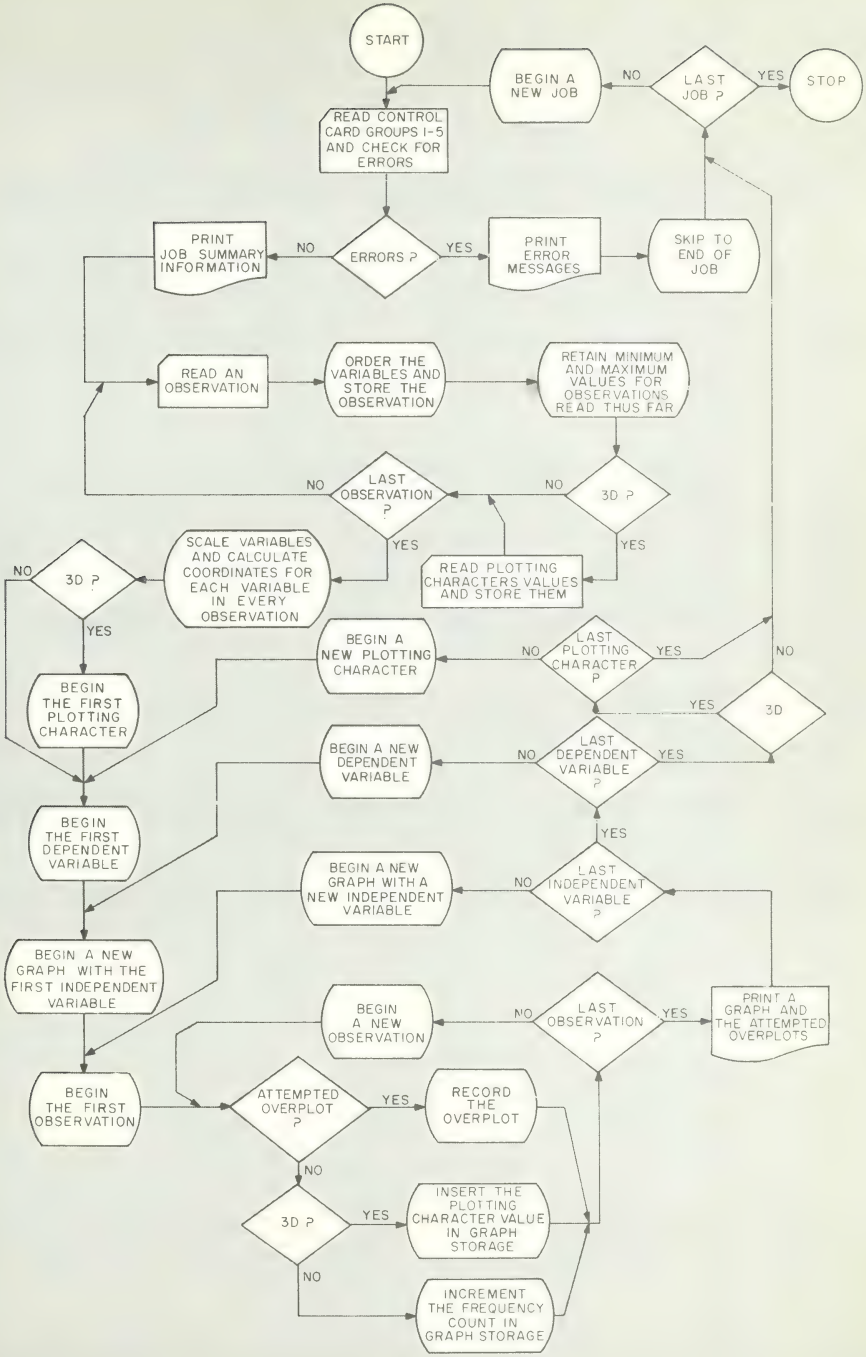


Figure 3.—SNOOP flow chart.

(NYS + NXS) X NOBS = XXXXXX
THIS MUST BE EQUAL TO OR LESS THAN 10,000

(NYS + NXS + NPC) X NOBS = XXXXXX
THIS MUST BE EQUAL TO OR LESS THAN 10,000

THE FOLLOWING CONTROL CARD IS MISPUNCHED OR OUT OF ORDER. . .
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXX

THERE IS A VARIABLE LABEL WITH THE 3D PLOTTING CHARACTER GROUP

THERE IS A NON-NUMERIC CHARACTER IN OBSERVATION XXX FOR PLOTTING CHARACTER XX

After any of the above messages are printed, the following message is printed:
UNABLE TO PROCESS THIS JOB
THE PROGRAM IS NOW SEARCHING FOR THE NEXT JOB (IF ANY)

APPENDIX

I

CONTROL-DECK EXAMPLE

```
3D01010109 51RED PINE VOLUME TABLE CONSTRUCTION (PRELIMINARY PLOTTING)
1(5X,F3.1,5X,F4.1)
X                DIAMETER AT BREAST HEIGHT
Y                    CUBIC-FOOT VOLUME
PLOTTING CHARACTER 111 HT CLASS
      143   62   432
      145   72   513
      148   80   597
      150   46   351
      152   45   356
      153   40   317
      154   52   418
      156   68   561
      157   56   470
      159   75   640
      160   60   521
      163   73   657
      165   85   780
      168   80   770
      170   50   480
      173   60   609
      175   56   570
      177   58   617
      178   64   694
      179   72   790
      180   58   630
      181   69   766
      183   62   704
      184   74   840
      186   76   900
      188   64   788
      131   44   250
      132   56   335
      134   48   292
      136   47   290
      137   53   338
      139   56   369
      140   59   390
       50   20    17
       51   22    19
       52   26    25
       54   28    23
       56   24    26
       59   36    42
       60   30    36
       62   33    43
       63   24    33
       65   26    38
       65   36    52
       70   40    66
```

CONTINUED

```
 72  39   69
 74  42   79
 77  42   82
 79  45   94
 80  46  100
 83  45  102
 86  50  123
 90  30   94
 92  35  101
 94  36  111
 97  44  140
111  58  242
100  51  175
101  40  138
103  52  187
104  48  174
106  55  209
189  84 1030
193  70  880
198  90 1222
109  58  234
110  39  160
199  86 1141
200  60  801
 99  38  123
119  45  216
219  82 1330
220  95 1592
221  98 1634
223  74 1263
225  86 1530
119  65  315
120  54  260
126  70  377
230  60 1036
233  95 1750
130  40  235
130  42  241
240  97 1894
261  60 1360
263 100 2371
266  87 2104
268 101 2453
280 102 2763
113  40  170
115  64  283
202  72 1002
210  74  983
218  75 1223
116  43  199
CONTINUE
2D01020009$1RED PINE DATA - EXAMPLES OF TWO-DIMENSIONAL PLOTTING)
1(5X,F3.1,1X,F3.0,1X,F4.1)
X              DIAMETER AT BREAST HEIGHT
X                   TOTAL HEIGHT
Y                 CUBIC-FOOT VOLUME
(SAME OBSERVATION DECK AS USED FOR THE FIRST JOB MUST BE INSERTED HERE)
DONE
```

II
OUTPUT FOR CONTROL DECK GIVEN IN I.

```
 JOB NUMBER   1
 JOB TITLE =RED PINE VOLUME TABLE CONSTRUCTION (PRELIMINARY PLOTTING)
 3D PLOTTING

 NUMBER OF DEPENDENT(Y) VARIABLES = 1
 NUMBER OF INDEPENDENT(X) VARIABLES = 1
 NUMBER OF OBSERVATIONS = 95
 NUMBER OF CARDS PER OBSERVATION =1
 NUMBER OF PLOTTING CHARACTERS = 1

 THE CONTROL DECK FOR THIS JOB IS.....

 3D 1 1 1 95RED PINE VOLUME TABLE CONSTRUCTION (PRELIMINARY PLOTTING)
 1(5X,F3.1,5X,F4.1)
 X              DIAMETER AT BREAST HEIGHT
 Y                    CUBIC-FOOT VOLUME
 PLOTTING CHARACTER 111 HT CLASS

 ....OBSERVATION CARDS ARE LOCATED HERE....

 THE VARIABLES IN THE FIRST OBSERVATION ARE...
 Y( 1)= 0.4320000E 02
 X( 1)= 0.1430000E 02

 THE PLOTTING CHARACTERS FOR THIS OBSERVATION ARE....
 PC( 1)=6
```

```
                    JOB NUMBER   1
                    RED PINE VOLUME TABLE CONSTRUCTION (PRELIMINARY PLOTTING)
                    THREE-DIMENSIONAL GRAPH,PC( 1) IS DEFINED AS HT CLASS
      0.2736E 03..                                                                                                  0
                 .
                 .
                 .
                 .                                                                                                  0
                 .
                 .                                                                                                  0
                 .
                 .
      0.2186E 03..                                                                                                  8
                 .
                 .
                 .
                 .                                                                                          9
   C             .
   U             .                                                                                        9
   B             .
   I             .                                                                                      9
   C  0.1637E 03..                                                                                     9
   -             .
   F             .                                                                                    9  8
   O             .
   O             .                                                                                              6
   T             .                                                                                   8
   V             .                                                                                    7
   O             .                                                                          9         7
   L             .                                                                          8
   U  0.1088E 03..                                                                  8                 6
   M             .                                                                        7  7
   E             .                                                                 7
                 .                                                              7
                 .                                                        7 7 6    6
                 .                                                     88    6
                 .                                                        6 6
                 .                                                        5
                 .                                                  8
                 .                                                  655
      0.5387E 02..                                            7     66
                 .                                                5     5
                 .                                              6    5
                 .                                           7    55   44
                 .                                        6     545     4
                 .                                     5 6 5    44 4
                 .                                  555  4 4    4
                 .                              4544   34
                 .                        444445  333  3
                 .                  2223332  43
     -0.1046E 01..................................................................................................
                 .                    .                    .                    .                    .                    .
                0.4885E 01           0.9485E 01           0.1408E 02           0.1869E 02           0.2329E 02           0.2789E 02

                                    DIAMETER AT BREAST HEIGHT
 NUMBER OF ATTEMPTED OVERPLOTS=  4
```

```
 COORDINATES OF ATTEMPTED OVERPLOTS
 Y= 0.4446E 01   X= 0.5115E 01   PC= 2
 Y= 0.4446E 01   X= 0.5115E 01   PC= 2
 Y= 0.4446E 01   X= 0.6265E 01   PC= 2
 Y= 0.4446E 01   X= 0.6495E 01   PC= 3
```

```
 CONTINUE
```

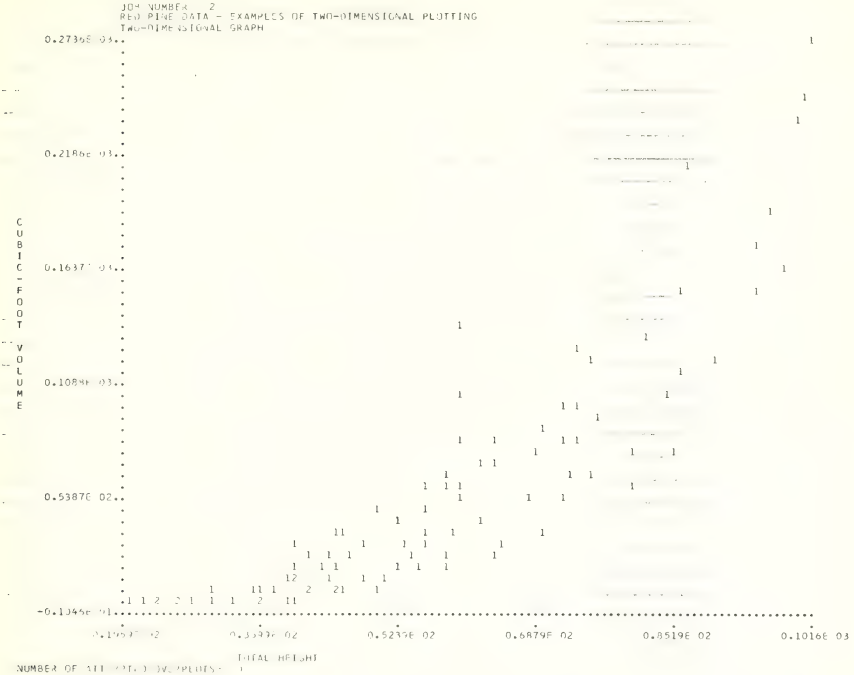
CONTINUED

```
JOB NUMBER  2
JOB TITLE  RED PINE DATA - EXAMPLES OF TWO-DIMENSIONAL PLOTTING
2D PLOTTING

NUMBER OF NON-IDENTITY VARIABLES = 1
NUMBER OF INDEPENDENT VARIABLES = 1
NUMBER OF OBSERVATIONS = 75
NUMBER OF CARDS PER OBSERVATION = 1
NUMBER OF PLOTTING CHARACTERS = 3

THE CONTROL DECK FOR THIS JOB IS.....

2D 1 2 0 RED PINE DATA - EXAMPLES OF TWO-DIMENSIONAL PLOTTING
1(5X,F3.1,1X,F3.0,1X,F4.1)
X          DIAMETER AT BREAST HEIGHT
X             TOTAL HEIGHT
Y             CUBIC-FOOT VOLUME

....OBSERVATION CARDS ARE LOCATED HERE....

THE VARIABLES IN THE FIRST OBSERVATION ARE...
Y( 1)= 0.4320000E 02
X( 1)= 0.1400000E 02
X( 2)= 0.6200000E 02
```

```
JOB NUMBER  2
RED PINE DATA - EXAMPLES OF TWO-DIMENSIONAL PLOTTING
TWO-DIMENSIONAL WORM
 0.2736E 03..                                                                                                  1
                .
                .
                .                                                                                        1
                .
                .                                                                                     1
                .
                .
 0.2186E 03..                                                                                            1
                .
                .
                .                                                                                  1
C               .
U               .                                                                                1
B               .
I               .
C  0.1637E 03..                                                                          1
F               .                                                                     1 1
O               .
O               .                                                                                  1
T               .                                                                  1
                .                                                                     1
V               .                                                                  1
O               .                                                              1      1
L               .                                                                 1
U  0.1088E 03..                                                                1        1
M               .                                                           1
E               .                                                        1     1 1
                .                                                     1
                .                                                  1 1 1    1
                .                                               11    1
                .                                            1 1      1
                .                                         1     111
 0.5387E 02..                                          1    11
                .                                            1
                .                                         1     1
                .                                      1   11   11
                .                                   1     111     1
                .                                1  11  1 1   1
                .                             111  1 1    1
                .                          1111  11
                .                      111111 111 1
                .                   3111122 11
-0.1046E 01.....................................................................................................
          0.4485E 01          0.9485E 01          0.1408E 02          0.1869E 02          0.2329E 02          0.2789E 02
                                    DIAMETER AT BREAST HEIGHT
NUMBER OF ATTEMPTED OVERPLOTS=  0
```

CONTINUED

Output For Control Deck. — Continued.



DONE

III
LISTING OF PROGRAM SNOOP.

```
      DIMENSION FMT(36),LABEL(50,50),ILABEL(50,50),CONLAB(10,2),TITLE(15
     1),IVAR(50),CHECK(5),IPC(10),XMAT(10120),PC(10),V(50),VV(50),KPC(72
     20),R(20),IGRAPH(50,100),XABS(5),IG(12)
C
C
C READ THE CONTROL DECK AND CHECK FOR ERRORS
C
C
C READ THE JOB DESCRIPTION CARD
      IJOB=0
 799  IJOB=IJOB+1
      READ(5,700)DEM,NYS,NXS,NPC,NOBS,NCARDS,(TITLE(I),I=1,15)
 700  FORMAT(A2,3I2,I3,I1,15A4)
      NC=NCARDS
      IF(NCARDS.EQ.0)NC=1
      IF(NCARDS.EQ.0)NCARDS=0
      WRITE(6,7501)IJOB
      WRITE(6,7511)(TITLE(I),I=1,15)
      WRITE(6,752)DEM
      WRITE(6,753)NYS
      WRITE(6,754)NXS
      WRITE(6,755)NOBS
      WRITE(6,10001)NC
10001 FORMAT(34H NUMBER OF CARDS PER OBSERVATION =I1)
      WRITE(6,756)NPC
      WRITE(6,757)
 7501 FORMAT(11H1JOB NUMBERI3)
 7511 FORMAT(12H JOB TITLE =15A4)
 752  FORMAT(1H A2,9H PLOTTING)
 753  FORMAT(35HONUMBER OF DEPENDENT(Y) VARIABLES =I2)
 754  FORMAT(37H NUMBER OF INDEPENDENT(X) VARIABLES =I2)
 755  FORMAT(25H NUMBER OF OBSERVATIONS =I3)
 756  FORMAT(32H NUMBER OF PLOTTING CHARACTERS =I2)
 757  FORMAT(43HOTHE CONTROL DECK FOR THIS JOB IS.....     )
      DATA THREED/2H3D/
      DATA TWOD/2H2D/
      IF(DEM.NE.THREED.AND.DEM.NE.TWOD)GO TO 999
      IF(NYS.LE.0.OR.NYS.GE.50)GO TO 800
      IF(NXS.LE.0.OR.NXS.GE.50)GO TO 801
      IF(NOBS.LT.2.OR.NOBS.GT.500)GO TO 810
      IF(DEM.EQ.THREED)GO TO 702
      IF(NPC.NE.0)GO TO 802
      IF(((NYS+NXS)*NOBS)-10000)703,703,860
 702  IF(NPC.LE.0.OR.NPC.GT.10)GO TO 803
      IF(((NYS+NXS+NPC)*NOBS)-10000)703,703,861
 703  WRITE(6,704)DEM,NYS,NXS,NPC,NOBS,NCARDS,(TITLE(I),I=1,15)
 704  FORMAT(1HOA2,3I2,I3,I1,15A4)
C READ THE FORMAT CARDS
      READ(5,780)IFORM,(FMT(I),I=1,18)
 780  FORMAT(I1,17A4,A3)
      IF(IFORM.LT.1.OR.IFORM.GT.2)GO TO 999
      WRITE(6,781)IFORM,(FMT(I),I=1,18)
 781  FORMAT(1H I1,17A4,A3)
      IF(IFORM.EQ.1)GO TO 706
      READ(5,705)(FMT(I),I=19,36)
 705  FORMAT(18A4)
      WRITE(6,782)(FMT(I),I=19,36)
 782  FORMAT(1H 18A4)
C READ THE VARIABLE LABELS
 706  NVAR=NYS+NXS
```

CONTINUED

```
      IXX=0
      IYY=0
      DO 790 I=1,50
  790 IVAR(I)=0
      DO 707 I=1,NVAR
      READ(5,708)VAR,(LABEL(I,K),K=1,50)
  708 FORMAT(A1,1X,50A1)
      DATA YY/1HY/
      DATA XX/1HX/
      IF(VAR.NE.YY.AND.VAR.NE.XX)GO TO 999
      IF(VAR.EQ.XX)GO TO 709
      IYY=IYY+1
      IVAR(I)=IYY
      GO TO 710
  709 IXX=IXX+1
      IVAR(I)=IXX+NYS
  710 WRITE(6,791)VAR,(LABEL(I,K),K=1,50)
  791 FORMAT(1H A1,1X,50A1)
C     ORDER THE VARIABLE LABELS
      KKK=IVAR(I)
      DO 711 K=1,50
  711 ILABEL(KKK,K)=LABEL(I,K)
  707 CONTINUE
C READ THE PLOTTING CHARACTERS LABELS
      IF(DEM.EQ.TWOD)GO TO 751
      DO 750 I=1,NPC
      READ(5,712)(CHECK(IJ),IJ=1,5),ICARD,IPC(I),(CONLAB(I,K),K=1,2)
  712 FORMAT(A2,4A4,1X,I1,I2,1X,2A4)
      IF(CHECK(1).EQ.YY.OR.CHECK(1).EQ.XX)GO TO 830
      DATA T1,T2,T3,T4,T5/2HPL,4HOTTI,4HNG C,4HHARA,4HCTER/
      IF(CHECK(1).NE.T1.OR.CHECK(2).NE.T2.OR.CHECK(3).NE.T3.OR.CHECK(4).
     1NE.T4.OR.CHECK(5).NE.T5)GO TO 999
      IF(IPC(I).LE.0.OR.IPC(I).GT.80)GO TO 999
      WRITE(6,792)(CHECK(IJ),IJ=1,5),ICARD,IPC(I),(CONLAB(I,K),K=1,2)
  792 FORMAT(1H A2,4A4,2I2,1X,2A4)
      IC=ICARD
      IF(IC.EQ.0)IC=1
      IPC(I)=((IC-1)*80)+IPC(I)
  750 CONTINUE
  751 CONTINUE
C
C
C THE OBSERVATIONS ARE NOW PLACED IN A VECTOR CALLED XMAT
C
C
      WRITE(6,797)
  797 FORMAT(45HO....OBSERVATION CARDS ARE LOCATED HERE....     )
      DO 100 K=1,50
      V(K)=0.0
  100 VV(K)=0.0
      DO 110 K=1,10120
  110 XMAT(K)=0.0
      ICOUNT=0
C READ THE VARIABLES
  103 READ(5,FMT)(V(K),K=1,NVAR)
      ICOUNT=ICOUNT+1
      IF(DEM.NE.THREED)GO TO 13
      DO 9691 IJKL=1,NC
C THE FOLLOWING CALL STATEMENT IS USED TO BACKSPACE THE INPUT UNIT
      CALL IOEDIT(1)
```

CONTINUED

```
 9691 CONTINUE
C READ THE PLOTTING CHARACTERS
      KSTART=1
      KEND=80
      DO 9692 IJKL=1,NC
      READ(5,112)(KPC(K),K=KSTART,KEND)
      KSTART=KSTART+80
 9692 KEND=KEND+80
  112 FORMAT(80A1)
      DO 113 I=1,NPC
      KKPC=IPC(I)
      IRKPC=KPC(KKPC)
      DO 960 LL=1,11
      DATA IG/1H ,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H./
      IF(IRKPC.NE.IG(LL))GO TO 960
      PC(I)=LL-1
      IF(LL.EQ.11)PC(I)=0.
      GO TO 113
  960 CONTINUE
      GO TO 835
  113 CONTINUE
      GO TO 13
10013 WRITE(6,970)
  970 FORMAT(54HOTHE PLOTTING CHARACTERS FOR THIS OBSERVATION ARE.... )
      DO 972 I=1,NPC
      L=PC(I)
  972 WRITE(6,971)I,L
  971 FORMAT(4H PC(I2,2H)=I1)
      GO TO 795
C ORDER THE VARIABLES
   13 DO 200 ISKIP=1,NVAR
      IP=IVAR(ISKIP)
  200 VV(IP)=V(ISKIP)
      IF(ICOUNT.NE.1)GO TO 795
      WRITE(6,7999)
 7999 FORMAT(48HOTHE VARIABLES IN THE FIRST OBSERVATION ARE...   )
      DO 650 I=1,NYS
  650 WRITE(6,651)I,VV(I)
  651 FORMAT(3H Y(I2,2H)=,E14.8)
      DO 652 I=1,NXS
      IXS=I+NYS
  652 WRITE(6,653)I,VV(IXS)
  653 FORMAT(3H X(I2,2H)=,E14.8)
      IF(DEM.EQ.THREED)GO TO 10013
C STORE THE VARIABLES
  795 KK=0
      DO 410 K=1,NVAR
      KSUB=((K-1)*NOBS)+KK+ICOUNT
      KMIN=KSUB+NOBS-ICOUNT+1
      KMAX=KMIN+1
      XMAT(KSUB)=VV(K)
      KK=KK+2
C STORE THE MAXIMUM AND MINIMUM VALUES
      IF(ICOUNT.EQ.1)GO TO 107
      AMAX=XMAT(KMAX)
      AMIN=XMAT(KMIN)
  120 IF((AMAX-VV(K))*(VV(K)-AMIN))106,106,410
  106 IF(VV(K)-AMAX)108,107,107
  107 AMAX=VV(K)
      XMAT(KMAX)=AMAX
```

CONTINUED

```
      IF(ICOUNT.NE.1)GO TO 410
  108 AMIN=VV(K)
      XMAT(KMIN)=AMIN
  410 CONTINUE
C STORE THE PLOTTING CHARACTERS
      IF(DEM.NE.THREED)GO TO 500
      DO 401 L=1,NPC
      KSLOT=(NOBS+2)*(NVAR+L-1)+ICOUNT
  401 XMAT(KSLOT)=PC(L)
  500 IF(ICOUNT.NE.NOBS)GO TO 103
C
C
C THE VALUES IN XMAT ARE CHANGED TO ROW AND COLUMN NUMBERS FOR THE
C           OUTPUT MATRIX(IGRAPH)
C
C
      KX=1
      DO 1050 K=1,NVAR
      NL=(K-1)*NOBS+KX
      ML=(NOBS*K)+KX-1
      KX=KX+2
      DO 1050 LK=NL,ML
      IF(K.GT.NYS)GO TO 1010
      DIV=50.
      GO TO 1011
 1010 DIV=100.
 1011 XINC=(XMAT(ML+2)-XMAT(ML+1))/DIV
      IF(XINC.EQ.0.)XINC=1.0
      A=XMAT(ML+1)
      RXMAT=0.
 1007 IF(A.GT.XMAT(LK))GO TO 1006
      A=A+XINC
      RXMAT=RXMAT+1.
      GO TO 1007
 1006 XMAT(LK)=RXMAT
      IF(K.GT.NYS)GO TO 1020
      IF(XMAT(LK).LE.50.)GO TO 1050
      XMAT(LK)=50.
      GO TO 1050
 1020 IF(XMAT(LK).LE.100.)GO TO 1050
      XMAT(LK)=100.
      GO TO 1050
  800 WRITE(6,990)NYS
      GO TO 1000
  801 WRITE(6,991)NXS
      GO TO 1000
  802 WRITE(6,992)NPC
      GO TO 1000
  803 WRITE(6,993)NPC
      GO TO 1000
  810 WRITE(6,994)NOBS
      GO TO 1000
  830 WRITE(6,995)
      GO TO 1000
  835 WRITE(6,996)ICOUNT,I
      GO TO 1000
  860 NOVER=((NYS+NXS)*NOBS)
      WRITE(6,997)NOVER
      GO TO 1000
  861 NOVER=((NYS+NXS+NPC)*NOBS)
```

CONTINUED

```
      WRITE(6,998)NOVER
      GO TO 1000
C THE FOLLOWING CALL STATEMENT IS USED TO BACKSPACE THE INPUT UNIT
 999  CALL IOEDIT(1)
      READ(5,892)(R(I),I=1,20)
      WRITE(6,891)
      WRITE(6,893)(R(I),I=1,20)
      GO TO 1000
 990  FORMAT(5HONYS=I2,/44H NYS MUST BE GREATER THAN 0 AND LESS THAN 50)
 991  FORMAT(5HONXS=I2,/44H NXS MUST BE GREATER THAN 0 AND LESS THAN 50)
 992  FORMAT(5HONPC=I2,/44H NPC MUST BE BLANK OR 0                      )
 993  FORMAT(5HONPC=I2,/44H NPC MUST BE GREATER THAN 0 AND LESS THAN 11)
 994  FORMAT(6HONOBS=I3,/46H NOBS MUST BE GREATER THAN 1 AND LESS THAN 5
     101)
 995  FORMAT(63HOTHERE IS A VARIABLE LABEL WITH THE 3D PLOTTING CHARACTE
     1R GROUP)
 996  FORMAT(49HOTHERE IS A NON-NUMERIC CHARACTER IN OBSERVATION I3,24H
     1FOR PLOTTING CHARACTER I2)
 997  FORMAT(18HO(NYS+NXS) X NOBS=I6,/42H THIS MUST BE EQUAL TO OR LESS
     1THAN 10,000)
 998  FORMAT(22HO(NYS+NXS+NPC) X NOBS=I6,/42H THIS MUST BE EQUAL TO OR L
     1ESS THAN 10,000)
 891  FORMAT(60HOTHE FOLLOWING CONTROL CARD IS MISPUNCHED OR OUT OF ORDE
     1R...)
 892  FORMAT(20A4)
 893  FORMAT(1H 20A4)
 1000 WRITE(6,1001)
 1001 FORMAT(27HOUNABLE TO PROCESS THIS JOB/55H THE PROGRAM IS NOW SEARC
     1HING FOR THE NEXT JOB(IF ANY)  )
 1002 READ(5,1003)TAL
 1003 FORMAT(A4)
      DATA EE,CC/4HDONE,4HCONT/
      IF(TAL.EQ.EE)GO TO 2000
      IF(TAL.EQ.CC)GO TO 799
      GO TO 1002
 1050 CONTINUE
C
C
C CONSTRUCT THE GRAPHS (IGRAPH)
C
C
      IF(DEM.EQ.TWOD)NPC=1
      DO 2010 J=1,NPC
      DO 2010 K=1,NYS
      KX=(2*(K-1))+1
      KY=(2*NYS)+1
      LNYS=NYS+1
      DO 2010 L=LNYS,NVAR
      REWIND 9
      DO 2030 I=1,50
      DO 2030 M=1,100
 2030 IGRAPH(I,M)=100
      MT=(K-1)*NOBS+KX
      NK=(L-1)*NOBS+KY
      MK=NK+NOBS-1
      KY=KY+2
      ICNT=0
      ID=0
      DO 2011 LK=NK,MK
      IY=XMAT(MT)+.001
```

CONTINUED

```
      IX=XMAT(LK)+.001
      IF(DEM.EQ.THREED)GO TO 2015
      IF(IGRAPH(IY,IX).EQ.110)GO TO 3000
      IGRAPH(IY,IX)=IGRAPH(IY,IX)+1
      GO TO 2011
 3000 WRITE(9,3002)IY,IX
 3002 FORMAT(2I3)
      ID=ID+1
      GO TO 2011
 2015 ICNT=ICNT+1
      KSLOT=(NOBS+2)*(NVAR+J-1)+ICNT
      KPLOT=XMAT(KSLOT)+.001
      IF(IGRAPH(IY,IX).NE.100)GO TO 3001
      IGRAPH(IY,IX)=KPLOT
      GO TO 2011
 3001 WRITE(9,3003)IY,IX,KPLOT
 3003 FORMAT(3I3)
      ID=ID+1
 2011 MT=MT+1
      END FILE 9
      REWIND 9
C PRINT A GRAPH
      WRITE(6,3041)IJOB
 3041 FORMAT(1H115X,11HJOB NUMBER I3)
      WRITE(6,3040)(TITLE(I),I=1,15)
 3040 FORMAT(1H 15X,15A4)
      IF(DEM.EQ.THREED)GO TO 3042
      WRITE(6,3043)
 3043 FORMAT(1H 15X,23HTWO-DIMENSIONAL GRAPH      )
      GO TO 3044
 3042 WRITE(6,3045)J,(CONLAB(J,JC),JC=1,2)
 3045 FORMAT(1H 15X,27HTHREE-DIMENSIONAL GRAPH,PC(I2,16H) IS DEFINED AS
     12A4)
 3044 CONTINUE
      DO 3050 IY=1,50
      DO 3050 IX=1,100
      IF(IGRAPH(IY,IX).NE.100)GO TO 3051
      IGRAPH(IY,IX)=IG(1)
      GO TO 3050
 3051 IF(IGRAPH(IY,IX).GT.100)IGRAPH(IY,IX)=IGRAPH(IY,IX)-100
      DO 3053 I=1,10
      IF(IGRAPH(IY,IX).NE.I)GO TO 3053
      IGRAPH(IY,IX)=IG(I+1)
      GO TO 3050
 3053 CONTINUE
      IGRAPH(IY,IX)=IG(11)
 3050 CONTINUE
      YINC=XMAT(MT+1)-XMAT(MT)
      YINC=YINC/50.
      BEGIN=XMAT(MT+1)-(.5*YINC)
      DO 3055 IJK=1,50
      I=50-IJK+1
      IF(I.EQ.50.OR.I.EQ.40.OR.I.EQ.30.OR.I.EQ.20.OR.I.EQ.10)GO TO 3060
      WRITE(6,3061)ILABEL(K,IJK),(IGRAPH(I,II),II=1,100)
 3061 FORMAT(1H A1,14X,1H.100A1)
      GO TO 3055
 3060 WRITE(6,3063)ILABEL(K,IJK),BEGIN,(IGRAPH(I,II),II=1,100)
 3063 FORMAT(1H A1,2X,E11.5,2H..100A1)
 3055 BEGIN=BEGIN-YINC
 3071 WRITE(6,3070)BEGIN
```

CONTINUED

```
 3070 FORMAT(4H    E11.5,102H.....
     1.....  )
      WRITE(6,3080)
 3080 FORMAT(1H 15X,1H.19X,1H.19X,1H.19X,1H.19X,1H.19X,1H.)
      XINC=(XMAT(MK+2)-XMAT(MK+1))/100.
      XBEGIN=XMAT(MK+1)-(.5*XINC)
      DO 6070 IIJK=20,100,20
      IIIJK=IIJK/20
      XIK=IIJK
 6070 XABS(IIIJK)=XBEGIN+(XIK*XINC)
      WRITE(6,6071)XBEGIN,(XABS(I),I=1,5)
 6071 FORMAT(1H 10X,E11.5,5(9X,E11.5))
      WRITE(6,3081)(ILABEL(L,II),II=1,50)
 3081 FORMAT(1HO15X,50A1)
      WRITE(6,3082)ID
 3082 FORMAT(31H NUMBER OF ATTEMPTED OVERPLOTS=I3)
      IF(ID.EQ.0)GO TO 2010
      WRITE(6,3083)
 3083 FORMAT(37H1COORDINATES OF ATTEMPTED OVERPLOTS      )
C PRINT THE OVERPLOTS
      DO 3085 I=1,ID
      IF(DEM.EQ.THREED)GO TO 3090
      READ(9,4040)IY,IX
 4040 FORMAT(2I3)
      YI=IY
      YI=(BEGIN+(YI*YINC))
      XI=IX
      XI=(XBEGIN+(XI*XINC))
      WRITE(6,3091)YI,XI
 3091 FORMAT(3H Y=E11.5,3X,2HX=E11.5)
      GO TO 3085
 3090 READ(9,4041)IY,IX,KPLOT
 4041 FORMAT(3I3)
      YI=IY
      YI=(BEGIN+(YI*YINC))
      XI=IX
      XI=(XBEGIN+(XI*XINC))
      WRITE(6,3092)YI,XI,KPLOT
 3092 FORMAT(3H Y=E11.5,3X,2HX=E11.5,3X,3HPC=I2)
 3085 CONTINUE
 2010 CONTINUE
      READ(5,3020)TAIL,TAIM
      IF(TAIL.NE.EE.AND.TAIL.NE.CC)GO TO 999
 3020 FORMAT(2A4)
      WRITE(6,3021)TAIL,TAIM
 3021 FORMAT(1H12A4)
      IF(TAIL.EQ.CC)GO TO 799
 2000 CONTINUE
      STOP
      END
```

Acknowledgment

Credit is due James A. Shaffer, computer programmer at the Ohio State University Computer Center, for the initial concepts of the program described in this paper.

The author also expresses gratitude to Chester E. Jensen, former Biometrics Section Chief at the Northeastern Forest Experiment Station, for technical review and suggestions for improvement during the course of developing the program.

a TREETOP TRAMWAY SYSTEM for meteorological studies

by Raymond E. Leonard
and Arthur R. Eschner

U.S. FOREST SERVICE RESEARCH PAPER NE-92
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

Acknowledgments

THIS paper is a contribution from the Cooperative Watershed Management Research Unit of the State University of New York College of Forestry and the U. S. Forest Service's Northeastern Forest Experiment Station research unit at Syracuse, New York.

The authors gratefully acknowledge the support of Prof. S. W. Potter, manager of Pack Demonstration Forest, and Howard Wells, technician, Water Resources Institute, New York State University College of Forestry, Syracuse, New York.

a
TREETOP TRAMWAY SYSTEM
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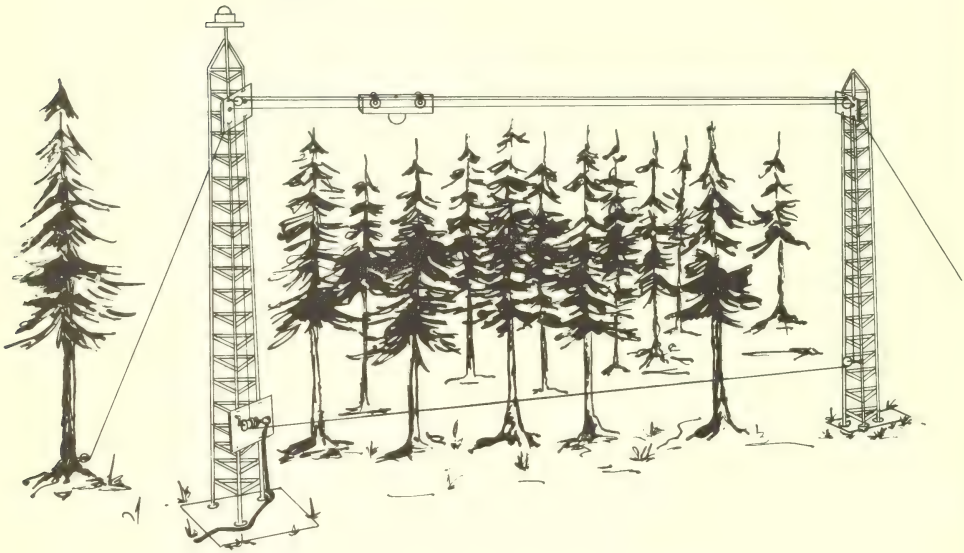
TO GET ABOVE THE TREETOPS

IN A RECENT STUDY of the solar radiation reflected by a red pine canopy, one of the first problems we had to solve was how to position measuring devices above the tree canopy. We considered two alternatives. Should we erect a number of towers or masts at various locations to hold radiation-measuring devices above the stand? Or should we erect a few towers and run a system of tramways among them so that the instruments could be moved around to different positions above the tree canopy?

The tramway system appeared to be less expensive; so we devised a system consisting of three 70-foot towers and two 100-foot tramways. This system, constructed at a cost of about $1,000 for materials, has been operated successfully for more than a year (fig. 1). Because of the ease of construction and the relatively low cost, other research workers might be interested in such a system.

Figure 1.—The tramway system consists of two towers with tramway cables between them. Instruments may be moved across the tramway to sample spatial variation in radiation, temperature, or other meteorological variables.



CONSTRUCTION

Towers

The towers we used to support the ends of the aerial tramway were of the type commonly used to hold television antennae. These are available through the major TV supply stores. Each section of the triangular steel tower is about 12 inches on a side and 10 feet long, and weighs around 35 pounds. A section can be handled easily by one man.

The base of the tower may be embedded in a section of concrete (3x3x3 feet) for permanent installation. For temporary installation the base section may be placed in a hole 2 or 3 feet deep, the bottom of which has a firm base of rock or concrete blocks. It is advisable to coat about 3 feet of the bottom section of the tower with tar or similar material before setting it in place. The hole is then refilled and tamped well. We used a carpenter's level to insure that the first section was plumb.

After the bottom section is firmly in place, the other sections are hoisted up; the three legs are slipped over the top of the previous section, and the two sections are bolted in place. We found that two men using standard lineman's safety belts could slip the two sections together without difficulty. However, an erection boom is commercially available to facilitate the hoisting and placement of the sections.

Steel guy cables should be attached at about 20-foot intervals on the tower. We found that 1/8-inch fiber-core steel cable was adequate for our purpose. Anchors for the cables should be placed at a considerable distance out from the base of the tower so the angle of the guy cable is a minimum of 60 degrees from vertical. A variety of anchoring systems may be used, including a concrete slab, commercial pole anchors, or tree stumps. We have found that a ½-inch diameter screw eye embedded in a sound tree stump as low as possible is satisfactory for our purposes.

Attachment of the guy cables to the tower and ground anchor follow standard procedures. Wire-rope thimbles should be used on all cable eyes. Two cable clamps, spaced 3 to 4 inches apart, were used to secure the cable eyes. Turnbuckles may be used to tighten the guy cables; however, we found it a simple task to take up the slack in the cable with a light block and tackle.

We used slightly slack guys. Our experience has been that at least 6 to 8 inches of slack per 100 feet of guy cable is preferred. Tree limbs and small trees may push against the guy cables during periods of high wind and cause considerable damage to the tower if the guy cables are stretched too taut.

One of the more frustrating problems in tower construction in the forest is to pass guy wires from the tower through the tree crowns at an angle to the ground. We tried several methods. We found that attaching a light line to a 6- or 8-foot pole and throwing it like a javelin down through the canopy worked fairly well. The light line was then used to pull the guy cable up to the tower. A bow and arrow equipped with a fishing reel might also work well. Guy cables were first attached to the tower and then were secured at the ground anchor and tightened. Three cables were used at each 20-foot guying level.

Tramway

To sample variation in reflected solar radiation above the canopy, an instrument must be placed in a stable level position above the canopy. Therefore the prerequisite of a good tramway system is to allow the instrument to move and yet hold the instrument in a level position.

To fasten the tramways to the towers, backing boards of ¾-inch exterior-grade plywood were attached to the towers at the desired height (fig. 2). Four U-bolts (¼ x 2 x 3½ inches) were used to secure each backing board to the inside legs of the tower.

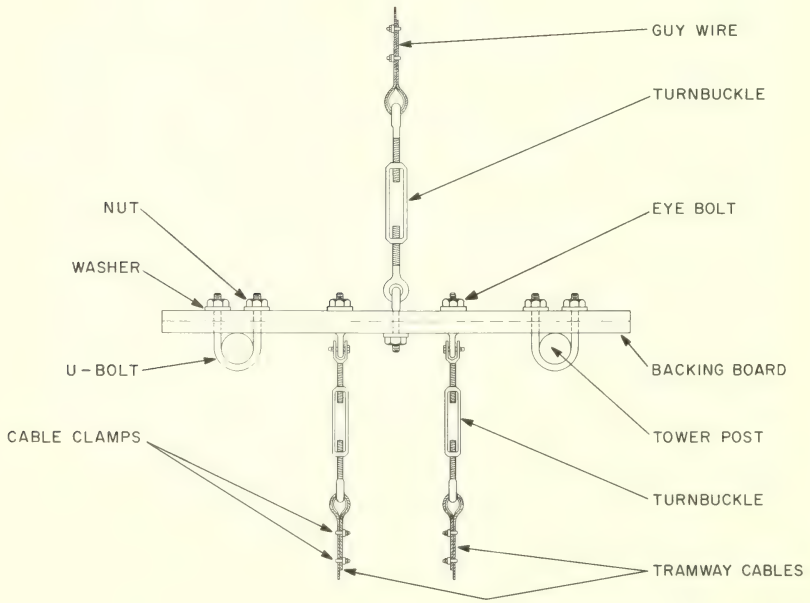


Figure 2.—Tramway cables were attached to the tower at a special backing board as shown in this construction drawing.

To secure the tramway cables to the backing board, two eyebolts (3/8 x 3 inches, drop-forged galvanized steel) were fastened to the face of each backing board, 6 inches apart in a horizontal line. A third eyebolt of the same size was set through the other side of the backing board, midway between the other two, for a guy line. The guy lines were needed here to take up the added strain that the tramways put on the tower.

For the tramway cables we used aircraft-grade steel cable (1/8-inch). To rig the cables to the backing board, we passed the cable end through the eye bolt, with a steel rope thimble, formed an eye in the cable around the thimble, and secured the free end of the cable to the standing end with two cable clamps spaced about 2 inches apart.

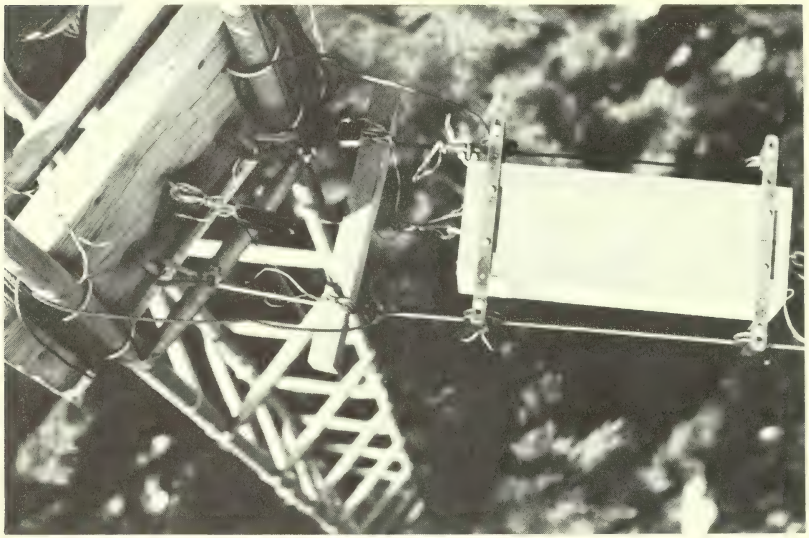
The guy cables to the backing board were rigged the same way. The other end of the guy cable was led to the ground at an angle of about 45 degrees and was secured to a convenient tree stump or was anchored to a deadman in the ground.

After the tramway cables were attached to one tower, they were led over to the other tower and were pulled taut with block and tackle. The cables were then secured to the other tower, to 6-inch turnbuckles (backed off 80 percent) secured to the eyebolts. The cables were then adjusted with the turnbuckles.

This was done by sighting along the tramway with a level and tightening the turnbuckles until the cable sag was less than 2 inches in the middle of the tramway. As the tramway cables were tightened, guy-cable turnbuckles were also adjusted to keep the tower plumb. Tower position was checked with a carpenter's level on the backing board. Final adjustment was made by placing an instrument equipped with a level bubble in the middle of the tramway and sighting on the bubble with binoculars.

A small tramway cart was built to hold the Kipp-Zonen solarimeter used in our studies. The cart consisted of a light-weight housing mounted on four flanged wheels that rode the tramway cables (fig. 3). The sensing unit of the solarimeter faced the tree canopy to measure reflected radiation.

Figure 3.—Looking down on the instrument housing and end of the tramway from the upper portion of the tower.



OPERATION

Hand Winch

With the towers up and the tramway in place, some method was needed to move the instrument car along the tramway. Several systems were tried, and we finally settled on a system involving an endless cable and winch. A simple crank-operated drum winch with a cylinder 8 inches in diameter was constructed of scrap materials. The crank was fabricated with 1-inch diameter copper pipe and elbows. Flat copper flanges were bolted on each end of the drum, and the copper pipe was soldered in place. The entire winch must be securely located, either bolted to a bench or to a post driven in the ground. We located the winch on a bench in a field laboratory a short distance from the base of one of the towers.

A light steel cable, 1/16 inch in diameter, was passed around the drum and then fed through pulleys attached to each tower so that the haulback cable traversed from the instrument bench over to the base of the more distant tower, up the outside of the

tower, then along between the tramway cables to the opposite tower, down the tower leg, and finally back to the instrument bench. A minimum of six pulleys was used; more might be required to position the cable correctly on the drum. All pulleys, like those used on motorboat steering mechanisms, were plastic, 3 inches in diameter.

The haulback cable had to be kept taut at all times to avoid slippage on the drum. This was accomplished by placing a heavy-duty door spring, 12 inches long, between the pulleys at the base of the towers and the point of attachment on the tower. The cable was pulled taut with block and tackle and secured with two cable clips.

To put the system in operation, we placed the instrument at one end of the tramway and turned the drum so that the haulback cable was attached to the instrument at the cable clip splice. When the instrument was attached to the cable at this point, turning the winch crank moved the instrument to any desired location on the tramway (fig. 4).

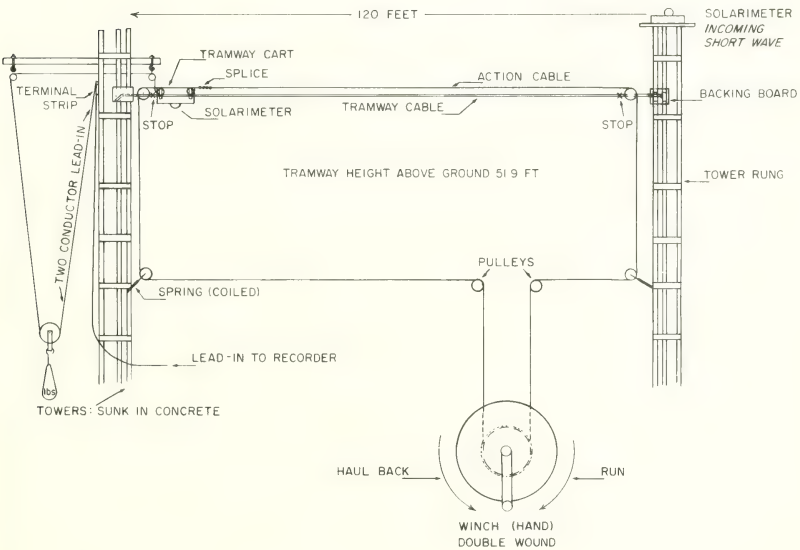


Figure 4.—A crank-operated drum winch may be used to move the instruments along the tramway.

Power Winch

To eliminate the inconsistent speed of hand-operated winches, we built a power winch from a ½-inch electric drill and a light boat winch. The lower of two gear ratios (4.1:1) was used. The handle was removed from the boat winch and a ½-inch hardened steel rod about 3 inches long was inserted into the drill chuck. A ½-inch flexible coupling was used to connect the drill and winch.

This power winch was then firmly attached to a double thickness of ¾-inch plywood mounted on a tower (fig. 5).

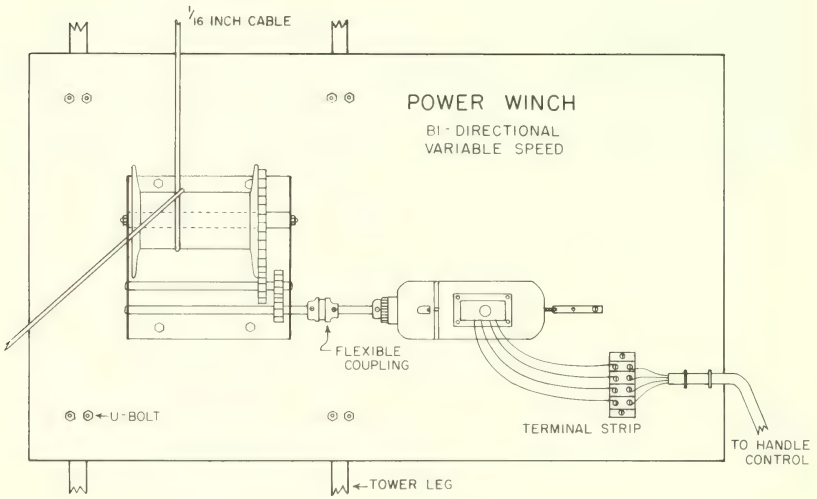


Figure 5.—A power winch built from a 1/2-inch electric drill and a light boat winch was used to move the instruments along the tramway.

A 20-foot extension wire was inserted between the drill motor and handle. This made it possible to keep the drill handle at the workbench while the winch was attached to the tower. The forward and reverse switch on the handle allowed the necessary directional run of the tramway.

The original diameter of the winch drum — about 1 inch — was too small to give the necessary speed. So we wound the

winch drum with wire, and about four layers of electrical tape over the wire, to build up the circumference to 12 inches. This gave the desired speed range.

A variac (variable auto transformer) was used between the 115-volt power line and the drill handle. This allowed the operator to vary the line voltage to the drill from about 20 volts to 120 volts and in turn vary the rate of speed of the cart as desired. With the 12-inch drum circumference, 4.1:1 gear ratio, and the variable voltage to the drill, we could run the tramway cart from tower to tower at rates of less than 1 minute to more than 10 minutes.

The electrical tape wrapping, coupled with a one and one-half lap of the tramway cable on the winch drum, permitted the cable to slip if the cart was accidentally run up against the stop at either end of the tramway. This protected the cart and solarimeter from damage. The tension of the tramway cable and the friction of the electrical tape prevented slippage under normal operating conditions.

When first put into operation, the power winch interfered with the accuracy of the millivolt recorder. This effect was more prominent when the drill was first started for a run. The large number of instruments being powered by the single line electrical line to the workbench caused a drop in voltage to the recorder. In addition, the highly sensitive millivolt recorder, when recording on 1 mv full scale, may have picked up radio waves produced by the armature and brushes of the drill.

The problem was partially solved when a second electrical line was brought to the workbench, with only the variac connected to it. This situation can also be relieved by the use of copper screen encasing the d.c. motor. This will filter out most of the d.c. interference. The radio waves apparently decreased sufficiently after more use of the drill so as not to affect the recorder.

A second power winch was built for the other tramway. The bearings of the boat winches were not designed for the frequent use at the relatively high speeds to which we subjected them. However, we believe that they will last for more than 1 year with frequent lubrication.

Recorder Hook-up

To read the output of the instrument on the tramway, we set up a system for running a two-conductor electric cable from the instrument bench to the tramway. The cable ended at a terminal strip located at the end of the tramway. A light two-conductor cable was run from the terminal strip to the instrument on the tramway. The wire was long enough to cover the entire distance between the two towers.

One end of this lead wire was attached to the terminal strip on the tower and clamped securely to the tower leg. The lead-in wire was then passed through a 6-inch-diameter weighted pulley that was free to move up and down the tower, keeping the lead wire taut. The wire then passed through a 3-inch-diameter pulley, attached between the tramway cable at a distance 1 foot out from the tower, and terminated at the instrument on the tramway (fig. 4). As the instrument moved out along the tramway the weighted pulley moved up the tower, keeping the lead wire at sufficient tension to eliminate disturbance of the field of measurement.

DISCUSSION

Although this system was designed primarily for sampling spatial variation in reflected shortwave radiation, it should be suitable for measuring several other meteorological variables such as net radiation or surface temperature.

Our experience with this system of cable tramways has been good. Two tramways have been in operation for over a year under all weather conditions without major problems.

The cost of this system is relatively low: metal tower sections were purchased at about $2.00 per lineal foot, and cable and wire are widely available and cost between 4 and 60 cents per foot. Construction costs were also favorable. Two men can erect two towers to a height of 70 or 80 feet and string the tramway in about 2 days without any outside equipment.

■

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

Ten-Year Average
GROWTH RATES
In The Spruce-Fir Region Of Northern New England

by Lawrence O. Safford

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U.S. FOREST SERVICE RESEARCH PAPER NE-93
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

The Author

LAWRENCE O. SAFFORD received his Bachelor of Science degree in forestry in 1961 from the University of Maine, and his Master of Forestry degree from Yale University School of Forestry in 1962. Since 1962 he has been on the staff of the Northeastern Forest Experiment Station's spruce-fir silviculture project at Orono, Maine.

THE QUESTION OF GROWTH

A COOPERATIVE spruce-fir growth study was begun in northern New England in 1950. By 1954 the cooperating landowners had established a total of 1,126 sample plots. The first remeasurement — after five growing seasons — was completed on 866 plots by 1958, and in 1961 a report was published about the average growth based on these remeasured plots.[1] The 5-year report showed that the average growth in the region was considerably greater than the previously used estimates.

By the fall of 1964, a second remeasurement covering 10 seasons of growth had been completed. Average growth rates for the 10-year period — based on 766 plots — are presented in this report.

The growth figures presented here are the answer to a question asked over 16 years ago — What is the wild forest land capable of producing on its own? The results suggest that the forests of 16 years ago grew at a rate sufficient to exceed the drain placed upon them in this period.[2]

In the 16 years since this study was begun, many changes have occurred. The chain-saw has replaced the ax and bucksaw, and it in turn is being challenged by tree-harvesting machines. River-driving has given way to truck-hauling; horses are giving way to crawler tractors and rubber-tired skidders; and so on.

And today, new questions are being asked about intensive forest-management practices designed to meet the ever-increasing

[1] Bickford, C. Allen, Franklin R. Longwood, and Robert Bain. AVERAGE GROWTH RATES IN THE SPRUCE-FIR REGION OF NEW ENGLAND. NE. Forest Exp. Sta., Sta. Paper 140, 23 pp., 1961.

[2] Maine Forest Service. PRIMARY PROCESSOR NEWS LETTER, 1950-1965. Mimeographed. Augusta, Maine.

demands placed upon our spruce-fir forests. The growth figures presented here provide a foundation upon which answers to these questions may be developed.

THE STUDY

The purpose of this study was to obtain estimates of the overall growth rates in the spruce-fir forests of northern New England. The study was designed to estimate the growth rate of the spruce-fir component with an accuracy of plus or minus 10 percent. It was assumed that the accuracy of estimate for the other species groups would be in proportion to their representation in the sample.

The growth of pulpwood species, especially spruce and fir, was our primary interest. In 1950, little value was placed on hardwood species for pulpwood; so sampling in hardwood stands was less intensive.

Sampling Design

Plots were distributed throughout the northern sections of Maine, New Hampshire, and Vermont (fig. 1). Details of the sampling procedure were reported by Bickford *et al.*[1] The sample consisted of randomly selected plots within 27 stand-condition classes. Nonstocked areas (less than 10 percent crown closure) were not sampled. Stand-condition classes were defined on the basis of three levels of stand type, stand height, and stand density, as follows:

Stand type
- S —Softwood (66 to 100 percent softwood species).
- M—Mixedwood (21 to 65 percent softwood species).
- H—Hardwood (0 to 20 percent softwood species).

Stand height
- 1—Less than 35 feet.
- 2—35 to 64 feet.
- 3—65 feet and taller.

Stand density
- A—71 to 100 percent crown closure.
- B—41 to 70 percent crown closure.
- C—11 to 40 percent crown closure.

Figure 1.—Distribution of sample plots from which 10-year growth rates were calculated. Numbers indicate plots in a single township.

Any condition class can be identified by three symbols; for example, S2B designates a stand that contained 66 to 100 percent softwood species, averaged 35 to 64 feet in height, and had 41 to 70 percent crown closure.

Where aerial photos were available, the stand condition classes were interpreted by a single experienced photogrammetrist to avoid possible differenes in interpretation among com-

panies. A stereogram illustrating some of the stand condition classes is presented in figure 2. Most of the photos used were taken in the late 1940's or early 1950's so they were up-to-date when interpretations were made. In cases where no photos were available, classification was made on the ground by the field crew. Since no differences between on-the-ground classification and photo-classification were found in the 5-year analysis,[1] all plots were combined for the 10-year analysis.

The field crews re-estimated condition class at the time of each remeasurement, and some changes from the initial classification were noted. However, no analysis of these changes was made, and study results are reported on the basis of the classification at the time of plot establishment.

In spite of efforts to obtain an adequate sample in each condition class, three of the classes (S3C, M3C, and H1C) were not sampled at all. On the other hand, another three classes (S2B, S2A, and M2B) made up 56 percent of the total plot sample (table 1). This irregularity in distribution may reflect the actual

Table 1.—Number of plots, by stand-condition class

Stand type and height class	Density class		
	11-40	41-70	71 or over
	No. plots	*No. plots*	*No. plots*
Softwood			
0-34 feet	3	14	43
35-64 feet	29	134	138
65 feet or over	0	3	7
Mixedwood			
0-34 feet	8	1	4
35-64 feet	25	161	56
65 feet or over	0	2	6
Hardwood			
0-34 feet	0	1	6
35-64 feet	54	28	25
65 feet or over	2	6	10

Figure 2.—Stereogram showing examples of some of the stand condition classes sampled. Interpretation by T. Tryon, J. W. Sewall Co., Old Town, Maine. Scale 1:15840; panchromatic film.

distribution of forest stands in nature. Or it may be the result of bias favoring the condition classes that held the greatest interest for the landowners.

The fact that only 766 of the 1,126 plots originally established were used in these calculations is testimony to the difficulties involved in long-term plot-remeasurement studies. Some plots were lost to natural causes — fire, flooding by beavers, and wind storms. Others were lost through forest-management activities — bulldozing of road systems or harvest cutting. Administrative action — sale of land or failure to remeasure — eliminated still others. The final category — human error — eliminated surprisingly few plots when all the chances for mistakes in relocating the plots, measuring the trees, and recording, transcribing, and processing the data are considered.

Growth Components

The change in sound merchantable wood volume from one point in time to another plus the volume of trees harvested during the period is called *net growth.* Net growth is the algebraic sum of *accretion*[3] (growth on trees present at both inventories plus volume added to trees that die or are cut during the interval), *ingrowth* (volume of trees that grew into the minimum size class during the measurement period), and *mortality* (final volume of trees that died or became unmerchantable during the measurement period). *Gross growth* is equal to accretion plus ingrowth. Since this study is concerned primarily with growth rates in natural stands, plots that had heavy cutting were excluded from the calculations.

The term *merchantable* puts certain size and quality limitations on the trees that make up the stand volume. In this study minimum sizes were the 5-inch d.b.h. class for softwoods and the 7-inch d.b.h. class for hardwoods. Minimum top diameter was 4 inches. Quality limitations were that a tree be satisfactory for

[3] Accretion is synonymous with the term "gross growth of initial volume" as defined in Beers, Thomas W., COMPONENTS OF FOREST GROWTH. J. Forestry 60: 245-248, 1962.

use as pulpwood. Species not widely used for pulpwood such as pine, cedar, and some of the hardwoods were judged on the same basis as comparable merchantable species. Any trees considered unsuited for pulpwood were called *cull*, and their volume was excluded from the calculations.

Many merchantable trees also contain defect that makes a part of their volume unmerchantable. There is now no available means of measuring this unseen or hidden defect in standing trees. Consequently, its influence on the growth figures reported here is not fully known. The cooperating companies estimate unseen defect by a wide range of methods that vary from simple rules of thumb to detailed tables for each species and size class. Deduction figures, which vary with tree species and size, range from 2 percent to over 25 percent of the total volume of the tree. In all cases the amount of defect increases with increasing tree size; thus as trees grow, a certain portion of this growth is cancelled by the increase in unseen defect.

Basic Data and Computations

Basic data for the study consisted of a tally by species and 1-inch d.b.h. classes of softwoods 4.5 inches d.b.h. and larger and of hardwoods 6.5 inches d.b.h. and larger. Separate records were kept of ingrowth, mortality, cull, and cut trees.

Basic data were converted to volumes, using Austin Cary's tables[4] as modified by procedures described in the earlier report.[1] Cary's table 8, which gives tree volume, exclusive of stump, to a 4-inch top, was used for all softwoods. Hardwood tables were the same ones used in the 5-year report. These tables were reviewed by foresters of the cooperating companies, and, based on company experience, were judged satisfactory for this study. All volume data represent cubic feet of wood without bark.

Volumes were computed on the basis of average heights, as determined from height-over-d.b.h. curves developed for each major species. These curves were prepared from data collected

[4] Cary, Austin. WOODSMAN'S MANUAL. Fourth Ed., 323 pp., Harvard University Press, Cambridge. 1932.

on four or five sample trees from each plot, augmented where necessary with data from forest-survey plots located in the same general area.

All computations were performed on an IBM 7090 computer, using a program written especially for this study.

In this study net growth was calculated by subtracting live merchantable volume at the beginning of the measurement period from live merchantable volume at the end of the period and adding the volume of any trees cut. (Net growth figures in the 5-year report did not include the volume of cut trees.) Mortality and ingrowth were calculated from individual tallies. Gross growth was obtained by adding mortality to net growth. Accretion was calculated by subtracting ingrowth from gross growth.

Volume data are presented in cubic feet of bark-free wood per acre per year. Appropriate conversion factors may be used to convert cubic feet to cords. The most widely used conversion factors are 85 cubic feet per rough cord (the figure used in this report wherever cord volumes are mentioned) or 96 cubic feet per peeled cord. Some of the effects of unseen defect discussed earlier might be overcome by choice of conversion factor. For example, a company that has rigid quality standards might adjust for unseen defect by using a conversion factor of 88 to 90 cubic feet per rough cord or 100 to 104 cubic feet per peeled cord.

The standard error of the mean and the sampling error are measures of confidence that have been calculated for the various growth estimates in this paper. The standard error of the mean ($S_{\bar{x}}$) for each stand condition class was calculated as follows:

$$S_{\bar{x}} = \sqrt{\frac{S^2}{n}}$$

where S^2 is variance within the class, and n is number of observations within the class. Standard errors for groups of individual classes were pooled to obtain the standard error for the group.

The standard error of the mean evaluates the relation of the sample mean to the true mean. The odds are approximately 2 to 1 (2 times out of 3) that the true mean of a population will fall within the interval of the sample mean plus and minus its standard error. Thus, since the mean growth of this study

sample is 41.9 cubic feet per acre per year and the standard error is 0.9 cubic feet per acre per year, the odds are 2 to 1 that the true mean growth lies between 41.0 and 42.8 cubic feet per acre per year. By increasing the interval to plus and minus 2 times the standard error, the odds are increased to approximately 19 to 1 (95 times out of 100). Thus, the odds are 19 to 1 that the true mean growth lies between 40.1 and 43.7 cubic feet per acre per year.

The sampling error is simply the standard error expressed as a percentage of the mean. Thus the sampling error (at 2 to 1 odds) of this sample mean is 2.1 percent ($0.9/41.9 \times 100 = 2.1$).

Analytical problems caused by unequal sample numbers, probable heterogeneity of variance, and interactions among components hindered rigorous testing of the influences of stand type, stand height, and stand density.

Differences among the three levels of each of these stand condition components were evaluated by comparing the confidence intervals formed by the class mean net growth and 2 times its standard error. Means whose confidence intervals did not overlap were considered to be significantly different at the 5-percent level. This is conservative, and it does not account for interaction among stand components. It was used because it provides a straightforward method of comparing means based on unequal sample numbers. As a check, Duncan's new multiple-range test[5] was also used for these comparisons, using a weighted average standard error term. Results of both techniques were the same.

[5] Steel, R. G. D., and J. H. Torrie. PRINCIPLES AND PROCEDURES OF STATISTICS. 481 pp. McGraw Hill Book Co. Inc., New York. 1960.

RESULTS AND DISCUSSION

Average annual increment by growth component varied widely among species groups and stand conditions (tables 2, 3, 4). The reliability of these growth estimates also varied widely, as evidenced by the sampling errors associated with net growth among stand-condition classes (table 5). Each of the stand-condition components — stand type, stand height, and stand density — influenced the growth components (table 6).

Stand type — or percent softwood species — appeared to be the most important factor influencing net growth. Means of all three stand types were clearly different from each other (fig. 3). Softwood stands had the greatest net growth; mixedwood stands

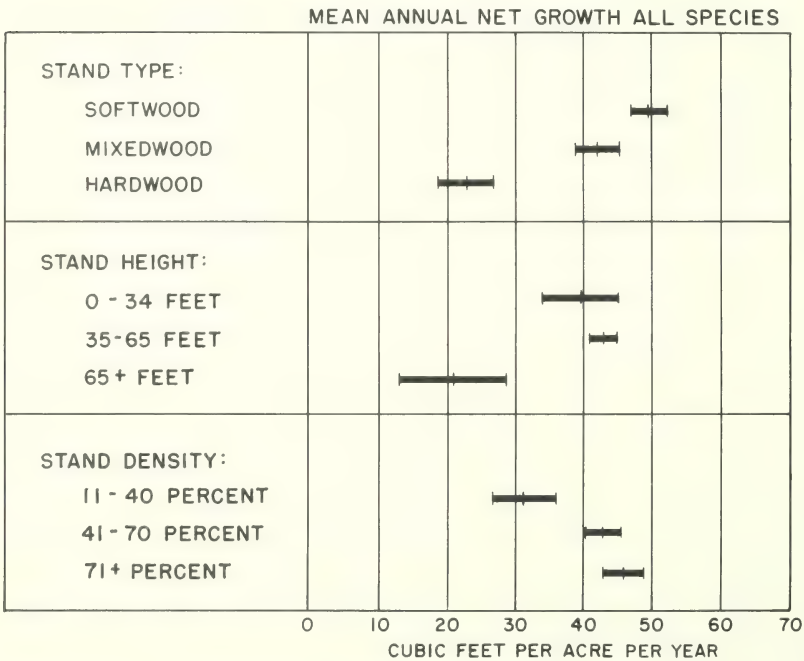

Figure 3.—Weighted mean net growth by stand type, height, and density classes with confidence intervals of 19 to 1 odds ($2S_{\bar{x}}$).

Table 2.—Average annual growth of softwoods, by components and stand-condition classes

Condition class			Plots	Spruce-fir-hemlock			All softwoods			
Type	Height	Density		Accretion	Ingrowth	Mortality	Accretion	Ingrowth	Mortality	Net[1] growth
	Feet	*Percent*	*No.*	*Cubic feet per acre*						
	0-34	11-40	3	8.8	1.1	0.9	12.2	1.1	0.9	12.4
Softwood	35-64	11-40	29	38.0	7.8	4.6	41.2	7.9	7.2	41.9
	65+	11-40	0	—	—	—	—	—	—	—
	0-34	41-70	14	32.9	8.9	3.4	34.6	9.1	3.7	40.0
Softwood	35-64	41-70	134	45.0	6.2	6.2	52.5	6.6	10.8	48.3
	65+	41-70	3	25.8	2.2	7.1	51.6	2.2	14.4	39.4
	0-34	71+	43	29.1	13.1	2.3	34.1	13.7	3.7	44.1
Softwood	35-64	71+	138	48.8	7.3	7.7	54.8	7.7	10.0	52.5
	65+	71+	7	40.7	3.1	11.1	48.8	3.5	14.6	37.7
	0-34	11-40	8	14.1	4.9	.5	14.1	4.9	.5	18.5
Mixedwood	35-64	11-40	25	36.1	6.6	4.8	37.0	6.7	6.3	37.4
	65+	11-40	0	—	—	—	—	—	—	—
	0-34	41-70	1	12.2	1.6	.0	12.9	1.6	.0	14.5
Mixedwood	35-64	41-70	161	33.1	4.8	5.2	37.3	5.0	6.8	35.5
	65+	41-70	2	25.1	5.5	12.6	28.0	5.5	20.4	13.1
	0-34	71+	4	34.1	5.8	1.4	35.8	5.9	1.7	40.0
Mixedwood	35-64	71+	56	38.4	5.7	7.7	41.2	5.9	7.9	39.2
	65+	71+	6	25.8	2.4	13.9	26.4	2.5	14.4	14.5
	0-34	11-40	0	—	—	—	—	—	—	—
Hardwood	35-64	11-40	54	10.8	3.0	1.3	0.8	3.0	1.3	12.5
	65+	11-40	2	3.5	.7	.0	3.5	.7	.0	4.2
	0-34	41-70	1	.0	.5	.0	.0	.5	.0	.5
Hardwood	35-64	41-70	28	10.5	1.9	3.4	10.9	2.0	3.6	9.3
	65+	41-70	6	6.6	1.1	4.5	7.8	1.1	4.5	4.4
	0-34	71+	6	7.0	.2	4.0	7.9	.2	4.0	4.1
Hardwood	35-64	71+	25	3.9	.9	1.6	3.9	.9	1.6	3.2
	65+	71+	10	6.7	.9	.0	6.7	.9	.0	7.6
All stands[2]	—	—	766	33.9	5.7	5.3	38.1	6.0	7.2	36.9

[1] May differ slightly from gross growth minus mortality because of rounding-off the calculations.
[2] Weighted average.

Table 3.—Average annual growth of hardwoods, by components and stand-condition classes

Condition class			Plots	Beech-birch-maple[1]			All hardwoods			
Type	Height	Density		Accretion	Ingrowth	Mortality	Accretion	Ingrowth	Mortality	Net[2] growth
	Feet	*Percent*	*No.*	*Cubic feet per acre*						
	0-34	11-40	3	0.0	0.8	0.0	0.0	0.8	0.0	0.8
Softwood	35-64	11-40	29	1.7	.9	3.3	1.3	1.0	3.9	— 1.6
	65+	11-40	0	—	—	—	—	—	—	—
	0-34	41-70	14	1.6	2.4	3.2	1.6	2.8	3.2	1.2
Softwood	35-64	41-70	134	3.3	2.3	4.6	3.8	2.7	5.1	1.4
	65+	41-70	3	1.7	1.4	4.0	1.7	1.4	4.0	— .9
	0-34	71+	43	.5	.1	.3	.5	.2	.3	.4
Softwood	35-64	71+	138	3.3	2.3	3.2	3.9	2.5	3.7	2.7
	65+	71+	7	.0	2.0	4.5	.1	2.3	4.5	— 2.1
	0-34	11-40	8	4.2	5.9	.8	5.7	11.5	2.6	14.6
Mixedwood	35-64	11-40	25	6.0	4.8	4.9	6.7	5.0	4.9	6.8
	65+	11-40	0	—	—	—	—	—	—	—
	0-34	41-70	1	6.9	16.4	.0	14.7	21.0	.0	35.7
Mixedwood	35-64	41-70	161	10.0	5.0	8.6	10.3	5.6	9.8	6.1
	65+	41-70	2	16.8	4.5	2.6	16.8	4.5	2.6	18.7
	0-34	71+	4	2.5	2.3	2.2	2.7	2.3	3.0	2.0
Mixedwood	35-64	71+	56	9.5	4.0	9.4	10.1	4.4	10.3	4.2
	65+	71+	6	14.1	2.8	31.4	14.1	3.1	31.9	—14.7
	0-34	11-40	0	—	—	—	—	—	—	—
Hardwood	35-64	11-40	54	14.1	6.4	13.6	14.6	6.9	13.9	7.6
	65+	11-40	2	10.0	12.4	.0	10.0	12.4	.0	22.4
	0-34	41-70	1	10.1	6.7	7.1	14.0	17.8	7.1	24.7
Hardwood	35-64	41-70	28	21.1	9.7	17.8	23.1	10.1	19.6	13.6
	65+	41-70	6	25.1	5.5	21.6	25.1	5.8	21.6	9.3
	0-34	71+	6	9.9	4.9	3.6	10.4	9.0	3.6	15.8
Hardwood	35-64	71+	25	12.9	11.2	9.6	22.3	16.9	12.0	27.2
	65+	71+	10	22.9	8.2	20.0	23.9	8.6	20.0	12.5
All stands[3]	—	—	766	7.3	4.0	7.0	8.1	4.6	7.7	5.0

[1] Includes beech, sugar maple, red maple, and yellow birch.
[2] May differ slightly from gross growth minus mortality because of rounding-off the calculations.
[3] Weighted average.

Table 4.—Average annual growth of all species, by components and stand-condition classes

Condition class			Plots	All species				
Type	Height	Density		Accretion	In-growth	Mor-tality	Net growth	Gross growth
	Feet	*Percent*	*No.*	- - -	*Cubic feet per acre*		- - -	
	0-34	11-40	3	12.2	1.9	0.9	13.4	14.1
Softwood	35-64	11-40	29	42.5	8.9	11.1	40.2	51.4
	65+	11-40	0	—	—	—	—	—
	0-34	41-70	14	36.2	11.9	6.9	41.4	48.1
Softwood	35-64	41-70	134	56.3	9.3	15.9	49.5	65.6
	65+	41-70	3	53.3	3.6	18.4	38.4	56.9
	0-34	71+	43	34.6	13.9	4.0	44.5	48.5
Softwood	35-64	71+	138	58.7	10.2	13.7	55.1	68.9
	65+	71+	7	48.9	5.8	19.1	35.6	54.7
	0-34	11-40	8	19.8	16.4	3.1	33.0	36.2
Mixedwood	35-64	11-40	25	43.7	11.7	11.2	44.4	55.4
	65+	11-40	0	—	—	—	—	—
	0-34	41-70	1	27.6	22.6	.0	50.4	50.2
Mixedwood	35-64	41-70	161	47.6	10.6	16.6	41.7	58.2
	65+	41-70	2	44.8	10.0	23.0	31.9	54.8
	0-34	71+	4	38.5	8.2	4.7	42.1	46.7
Mixedwood	35-64	71+	56	51.3	10.3	18.2	43.6	61.6
	65+	71+	6	40.5	5.6	46.3	.1	46.1
	0-34	11-40	0	—	—	—	—	—
Hardwood	35-64	11-40	54	25.4	9.9	15.2	20.1	35.3
	65+	11-40	2	13.5	13.1	.0	26.7	26.6
	0-34	41-70	1	14.0	18.3	7.1	25.4	32.3
Hardwood	35-64	41-70	28	34.0	12.1	23.2	22.8	46.1
	65+	41-70	6	32.9	6.9	26.1	13.8	39.8
	0-34	71+	6	18.3	9.2	7.6	19.8	27.5
Hardwood	35-64	71+	25	26.2	17.8	13.6	30.4	44.0
	65+	71+	10	30.6	9.5	20.0	20.1	40.1
All stands[2]	—	—	766	46.1	10.6	14.8	41.9	56.7

[1] May differ slightly from gross growth minus mortality because of rounding-off the calculations.

[2] Weighted average.

Table 5.—Mean annual net growth of all species, by stand-condition class, with associated standard errors and sampling errors at 2 to 1 odds

Condition class			Plots	Net growth	Standard error	Sampling error
Type	Height	Density				
	Feet	*Percent*	*No.*	*Cubic feet*	*Cubic feet*	*Percent*
	0-34	11-40	3	13.4	14.2	106
Softwood	35-64	11-40	29	40.2	4.6	11
	65+	11-40	0	—	—	—
	0-34	41-70	14	41.4	6.6	16
Softwood	35-64	41-70	134	49.5	2.1	4
	65+	41-70	3	38.4	14.2	37
	0-34	71+	43	44.5	3.8	8
Softwood	35-64	71+	138	55.1	2.1	4
	65+	71+	7	35.6	9.3	26
	0-34	11-40	8	33.0	8.7	26
Mixedwood	35-64	11-40	25	44.4	4.9	11
	65+	11-40	0	—	—	—
	0-34	41-70	1	50.4	24.6	49
Mixedwood	35-64	41-70	161	41.7	1.9	4
	65+	41-70	2	31.9	17.4	54
	0-34	71+	4	42.1	12.3	29
Mixedwood	35-64	71+	56	43.6	3.3	8
	65+	71+	6	.1	10.0	10,000
	0-34	11-40	0	—	—	—
Hardwood	35-64	11-40	54	20.1	3.4	17
	65+	11-40	2	26.7	17.4	65
	0-34	41-70	1	25.4	24.6	97
Hardwood	35-64	41-70	28	22.8	4.6	20
	65+	41-70	6	13.8	10.0	72
	0-34	71+	6	19.8	10.0	50
Hardwood	35-64	71+	25	30.4	4.9	16
	65+	71+	10	20.1	7.8	39
All stands	—	—	766	41.9	0.9	2.1

Table 6.—Weighted means of growth components for all species by stand condition class component

Condition-class component	Plots	Growth component				
		Accretion	Ingrowth	Mortality	Gross growth	Net growth[1]
	No.	*Cubic feet per acre per year*				
Stand type:						
Softwood	371	52.3	10.1	13.0	62.4	49.3
Mixedwood	263	46.8	10.7	16.5	57.5	41.1
Hardwood	132	27.5	11.8	16.8	39.3	22.5
Stand height:						
0-34 feet	80	31.2	12.9	4.6	44.1	39.5
35-64 feet	650	48.4	10.5	15.6	58.9	43.3
65 feet or over	36	37.9	7.4	24.2	45.4	21.3
Stand density:						
11-40 percent	121	32.4	10.3	12.0	42.7	30.7
41-70 percent	350	49.0	10.2	16.6	59.2	42.6
71 percent or over	295	48.4	11.1	13.9	59.5	45.6

[1] May differ slightly from gross growth minus mortality because of rounding-off the calculations.

were intermediate in net growth; and hardwood stands were much lower in net growth than either of the others. Hardwood species grew poorly regardless of the stand type in which they occurred. In hardwood stands — which were at least 80 percent hardwoods — hardwood species contributed only 61 percent of the net growth; in mixedwood stands — which were between 35 and 80 percent hardwoods — hardwood species contributed only 13 percent of the net growth (table 7).

The contribution of spruce and fir to net growth ranged from 86 percent (0.5 cord per acre) in softwood stands to 30 percent (0.1 cord per acre) in hardwood stands, and they accounted for 75 percent (0.4 cord per acre) of total net growth of all stands. Softwood species contributed 88 percent of the net growth on all plots. Softwood species even acocunted for 39 percent of the growth in hardwood stands. Most softwood species made their greatest growth in softwood stands, but hemlock made its greatest growth in mixedwood stands where it was most abundant. Cedar did equally well in softwood and mixedwood stands.

The greatest contributions to overall net growth by hardwood

Table 7.—Average annual net growth by individual species per acre

Species	Softwood stands		Mixedwood stands		Hardwood stands		All stands	
	Cubic feet	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*
Pine	1.5	3	0.2	1	0.1	(1)	0.8	2
Spruce	25.0	51	15.8	39	5.8	26	18.6	44
Fir	17.1	35	13.1	32	.8	4	12.9	31
Hemlock	2.3	5	4.3	10	1.9	9	2.9	7
Cedar	2.0	4	2.0	5	.1	(1)	1.5	4
Tamarack	.1	(1)	(2)	(1)	(2)	(1)	(2)	(1)
Total softwoods	48.0	98	35.5	87	8.7	39	36.7[3]	88
Sugar maple	(2)	(1)	0.8	2	4.4	19	1.1	3
Red maple	1.5	3	3.7	9	1.9	9	2.3	6
Yellow birch	—.8	—2	—.1	(1)	.2	1	—.4	—1
Paper birch	.4	1	1.0	2	.4	2	.6	1
Beech	.1	(1)	.1	(1)	3.5	16	.7	2
Aspen	.1	(1)	.2	(1)	2.5	11	.6	1
Miscellaneous[4]	(2)	(1)	—.1	(1)	.8	3	.1	(1)
Total hardwoods	1.3	2	5.6	13	13.7	61	5.0[3]	12
Total all species	49.3	100	41.1	100	22.4	100	41.7[3]	100

[1] Less than 0.5 percent.
[2] Less than 0.05 cubic feet.
[3] Differs slightly from overall average calculated on plot basis because of rounding-off calculations.
[4] Ash (white, green, black), basswood, cherry, elm, grey birch, hornbeam, and striped maple.

species were made by the maples, beech, aspen and white birch — a total of 13 percent (0.1 cord per acre). Red maple and white birch made their greatest growth in mixedwood stands. All other hardwood species made their greatest growth in the hardwood stands. Yellow birch had an overall negative net growth; only in hardwood stands did its growth factors exceed mortality.

One possible explanation for the slower growth of hardwood stands (and species) may be tree size. Because of the larger minimum diameter for hardwood species, the diameter of the tree of average basal area — calculated on the basis of 491 of these plots used in another study — was 11 inches versus 7 inches for softwoods. Thus many of the young vigorous hardwoods may

have been excluded and more emphasis placed on the larger, older trees that were perhaps less vigorous.

A large proportion of the plots (85 percent) in this study were in the 35- to 64-foot height class. Since so few plots were involved in the 0- to 34-foot and 65+-foot height classes, no strong statements can be made about the influence of height on net growth. However, the 65+-foot height class had significantly lower average net growth than the other two classes (fig. 3). The high mortality rate (table 6) for this height class is one reason for this result. Spruce-fir stands in this region do not grow much taller than 65 to 70 feet, even on the best sites, before the stands start to break up. There also may have been some confounding with stand types: of the 36 plots in the 65+-foot height class, 50 percent were in the hardwood stand type.

In general, net growth increased as stand density increased (table 6). The lowest class (11 to 40 percent) was significantly lower than the other two classes (fig. 3). This result differs slightly from the 5-year results, which showed the upper class (greater than 71 percent) significantly higher than the lower two classes. The low net growth in the lower density class was consistent for all stand types when the trees were less than 65 feet tall. Stands in the 11-to-40-percent density class and greater than 65 feet tall are apparently not common, for only two plots were sampled in these classes.

Comparison with 5-Year Results

The overall average annual net growth figure reported here is not significantly different from the overall average based on the 5-year remeasurement data (41.9 ± 1.8 versus 45.0 ± 3.0 cubic feet per acre). Doubling the length of the measurement period decreased variation even though 100 fewer plots were used in the calculation of the 10-year results. The standard error of mean annual net growth decreased from 1.5 cubic feet for the 5-year data to 0.9 cubic feet for the 10-year data. The corresponding sampling errors decreased from 3.3 to 2.1 percent. Ten-year mean values for condition classes that were based on a

large number of plots were closer to corresponding 5-year means than those 10-year values based on only a few plots.

Mortality expressed as a percent of net growth was slightly greater this time than for the 5-year figure (35 percent versus 26 percent). Ingrowth as a percent of accretion was decidedly lower than the 5-year figure (23 percent versus 47 percent), while the actual amount of accretion remained equal (46 cubic feet per acre per year). Thus it appears that a slight increase in mortality coupled with a decrease in ingrowth has added up to a slightly lower overall average growth figure than the 5-year results.

Using the Growth Figures

Strictly speaking, the growth figures presented in this report provide an estimate of how much the various forest condition classes grew under the conditions that existed during the measurement period. This fact must be recognized and the assumption made that conditions are equivalent when attempting to apply these figures to other areas of land for the purpose of estimating forest growth.

These data represent growth of natural stands that have had a minimum of past silvicultural treatment. In most cases stands were cut lightly in the past, and only the largest and best trees were removed. In some cases the residual stand was young and vigorous; in other cases poor-quality, low-vigor trees made the residual stand less desirable. Application of modern management techniques and silvicultural practices to present and future stands will influence the applicability of these growth estimates. Work should be directed toward developing stands wtih growth rates above our present wild levels by bringing the underproducing stands up to their full capacity. For example, net growth could be boosted to an annual average of 0.7 cord per acre by keeping present stands healthy and by harvesting the 35 percent of net growth that is currently lost to mortality.

On the other hand, application of management could have some negative aspects. Logging damage to residual trees could result in a period of increased mortality or larger numbers of cull trees, which could cause a decrease in net growth. Partial

cutting may result in stands susceptible to windthrow — another source of mortality. These are problems that the silviculturalist and forest manager will have to face in applying management to the forests. Certainly forest management should boost net growth above that possible under natural conditions.

There is always a risk involved in trying to apply averages to specific cases. In the case of these average growth figures the larger the forest area to be evaluated, the better the chances are that the estimated growth rate will be close to the true growth rate.

The best estimate of growth for any size of area can be obtained by using the individual stand-condition-class averages (tables 2, 3, 4). If the area is large — 5,000 acres or more — the average thus obtained will approach the overall average of 41.9 cubic feet per acre, and this figure may be used if one wants a quick estimate of growth for such a large area. Similarly for medium-sized areas — 1,000 to 5,000 acres — the averages by stand type (table 6) should provide adequate estimates of growth without detailed typing.

No shortcuts are possible with areas of 1,000 acres or less. The reliability of the estimate here depends on the distribution of stands within the original stand classification. If all or a major portion of the area is in one of the 27 condition classes for which a large number of plots was measured — S2C, S2B or M2B — the estimate of growth based on the figures from tables 2, 3 and 4 should be satisfactory. The large sampling errors for classes represented by small numbers of plots make estimates based on these classes unreliable.

Thus the use of these growth figures in predicting growth requires caution and judgment on the part of the user. A good knowledge of the stands to which the growth figures are to be applied is required. These stands should be natural — without silvicultural treatment — and should have a species composition similar to the sampled stands. If aerial photos are used to interpret stand-condition class, the age of the photos is of prime importance. Stand interpretation based on 10-year-old photos can

be used to estimate what the stand grew during the past 10-year period. To estimate future growth, current stand classifications obtained from new photos or on-the-ground interpretations should be used.

These average growth figures definitely should not be applied to plantations or other intensively managed stands or to cutover areas.

SUMMARY AND CONCLUSIONS

This report presents average annual values for the components of forest growth in the spruce-fir region of northern New England by stand-condition classes. A sample of 766 plots was used. The overall average annual net growth for all species was 41.9 cubic feet per acre with a sampling error of 2.1 percent. Sampling error decreased from 3.3 percent on the 5-year data even though there were 100 fewer plots in the sample. This 10-year average is lower than the previously reported 5-year average beacuse of a slight increase in the proportion of mortality and a fairly substantial decrease in ingrowth.

Softwood stands had the highest growth rates. Spruce and fir made major contributions to the growth of softwood stands and even contributed 30 percent of growth in hardwood stands. Hardwood stands and species had lower growth rates. These lower rates were at least partly explained by the higher minimum diameter for hardwood species.

These results provide a reliable estimate of growth in the natural extensively-managed stands of the region during the past 10-years. Precautions must be taken when using these results to predict future growth of forest stands.

These average growth rates can serve as a basis for forest managers to appraise the effects of their management practices. Silvicultural treatments that increase net growth above these wild stand rates should be sought and applied.

Acknowledgments

THIS report is a product of a cooperative study among ten northern New England timber-owning and forest-managing companies and the Northeastern Forest Experiment Station of the Forest Service, U. S. Department of Agriculture. The following companies established, maintained, and remeasured the sample plots used in this study: Brown Company, Dead River Company, Great Northern Paper Company, International Paper Company, Penobscot Development Company, St. Regis Paper Company, Scott Paper Company, James W. Sewall Company, Standard Packaging Corporation, and S. D. Warren Company.

These companies invested an estimated 4,800 man-hours gathering the data. Company representatives and University of Maine Forestry School faculty members served as an advisory committee during the planning and execution of the study.

The Northeastern Station had the overall responsibility for coordinating the study and for calculating the results. T. J. Grisez did the aerial photo interpretation of stand-condition classes. Data were processed by R. W. Wilson and W. B. Leak at the Yale Computer Center.

These contributions are gratefully acknowledged.

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PLANTING SITE, SHADE, & LOCAL SEED SOURCE:

Their effects on the emergence & survival of eastern white pine seedlings

by Raymond E. Graber

U.S. FOREST SERVICE RESEARCH PAPER NE-94
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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PLANTING SITE, SHADE, & LOCAL SEED SOURCE:

Their effects on the emergence & survival of eastern white pine seedlings

THE PURPOSE of our study was to examine some of the factors that influence seedling emergence and seedling survival of direct-seeded white pine (*Pinus strobus* L.). Our major concern was the response of white pine to a particular set of growing conditions as determined by the planting site and the shade treatment. We were especially interested in the effects of these growing conditions on the seedling emergence pattern, on seedling survival, and on the causes of seedling morality.

Local seed sources were used because the results of recent studies suggest that certain seed sources may be better adapted than others to the rigorous conditions that often exist during the period of germination and seedling establishment. Irgens-Moller[1] showed that Douglas-fir seed collected on a southern aspect germinated nearly twice as fast as seed collected on the northern aspect of the same hill. Rapid germination would definitely favor survival on hot, dry, south-facing slopes. Zobel *(1959),* working

[1] Personal correspondence with H. Irgens-Moller, 1960.

in Texas and Louisiana, found that survival of loblolly pine seedlings from seed collected from moist sites was about nil, while seed collected from drier sites only a few miles farther north produced very drought-hardy seedlings.

METHODS AND MATERIALS

Five seed lots were collected within a 30-mile radius in southwestern Maine. Each collection was made from five or more trees. Soil drainage at each location was classified according to the method of Husch and Lyford (*1956*). Descriptive information about the seed lots and the soil drainage at each location is presented in table 1.

Seed from the air-dried cones was extracted and cleaned by hand. Empty and partially filled seed were removed by winnowing. The seed was stored in sealed containers at 36°F. for 4 weeks before sowing in early November.

Two old-field planting sites were selected to provide a wide range in natural soil-moisture regimes. One soil was a moist Sutton loam with a relatively high moisture-holding capacity. The soil drainage class was moderately well-drained. The other site

Table 1.—Seed and soil drainage information

Seed source	Seed per pound	Seed viability[1]	Soil drainage class
	No.	*Percent*	
North Fryeburg	21,300	99.5	Excessively drained
Acton	24,000	99.0	Somewhat excessively drained
Alfred	17,700	98.5	Somewhat excessively drained
Lovell	24,000	87.5	Well-drained
Lebanon	20,900	94.0	Moderately well-drained

[1] Based on laboratory germination test.

was a droughty Windsor loamy sand. This excessively drained soil had a very low moisture-holding capacity.

Although the two planting sites differed in many ways, including differences in fertility, pH, and texture, the main difference was in their relative ability to store moisture near the surface and thus favor or restrict seed germination and initial seedling survival.

In preparation for planting, both sites were plowed and disked. During the growing season, all plots were hand-weeded frequently to control herbaceous competition.

We tested two light-intensity treatments by placing separate covers over each of 24 small seeding locations or units at each site. Light shade — 85 percent of full light — was provided by covers of No. 2 mesh hardware cloth. Heavy shade — 40 percent of full light — was provided by attaching Lumite Saran[2] shade cloth to the top and sides of hardware cloth covers. These covers also served to exclude small mammals and birds.

The 24 seeding units at each site were arranged in 6 blocks of 4 units each. Two units were given light shade, and two units were given heavy shade. There were five rows per unit, one randomly assigned to each of the seed sources. Rows were spaced 6 inches apart, and each row was sown with 20 seeds at 1-inch intervals. Seeds were pressed into the soil surface and then were covered with 1/3 inch of soil. The sowing was completed in November 1961.

Starting in early May, observations were made twice each week to record seedling emergence and mortality. As each seedling emerged, it was marked with a color-coded toothpick. When mortality occurred, the marker was removed, and the cause of death was recorded. The final observation was made in late October 1962.

For the subsequent statistical analysis of data, the two seeding units under each light intensity in a block were treated as one plot, and the two rows of each seed source in a plot constituted

[2] Mention of a particular product does not imply endorsement by the Forest Service or the U. S. Department of Agriculture.

a subplot. That is, in each block, the data from two similarly shaded rows of the same seed source were averaged and handled as single observations. The treatments and seed sources were tested for significance at the 5-percent level of probability by analysis of variance for a split-plot experiment nested within two sites.

RESULTS AND DISCUSSION

Total Emergence

Emergence was good: an overall average of 76 percent of the viable seeds produced a seedling. The effect of seed source on seedling emergence was not statistically significant. Differences among the five seed sources were small and could not be logically related to soil drainage at the seed collection sites (table 2).

Planting site, shade intensity, and their interaction — site x shade — significantly affected seedling emergence. The interaction between the planting site and the shade intensity reflects the major influence of soil moisture on germination and seedling emergence (fig. 1).

Moisture at and near the soil surface of the coarse, excessively drained soil (dry site) was rapidly depleted by evaporation, and thus the moisture supply was critically low much of the time.

Table 2.—Emergence of viable seed from five local sources in order of increasing moisture at seed-collection site

Seed source	Seedling emergence
	Percent
North Fryeburg	78
Acton	71
Alfred	75
Lovell	79
Lebanon	75

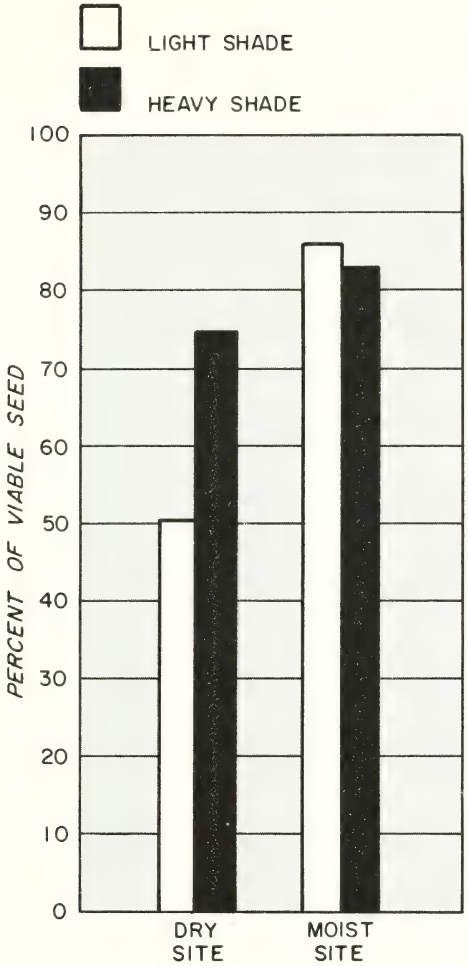

Figure 1.—Total seedling emergence as affected by planting site and shade intensity.

This lack of an adequate moisture supply is believed to be the major factor limiting seed germination and subsequent emergence on the lightly shaded plots on this site. Although moisture was still believed to be less than optimum on the heavily shaded plots, the periods of moist conditions favorable for germination were much longer. This was due to the greatly reduced insolation and air movement. After periods of light rainfall of 0.10 to 0.25 inches, the heavily shaded plots would remain moist at the soil surface for 1½ days or longer, whereas the lightly shaded plots were usually surface-dry in ½ day.

Available water in the imperfectly drained loam (moist site) was ample; this soil remained moist to the surface on all plots during the entire period of germination and emergence in May and June. As a result there was no increase in emergence under the heavy shade.

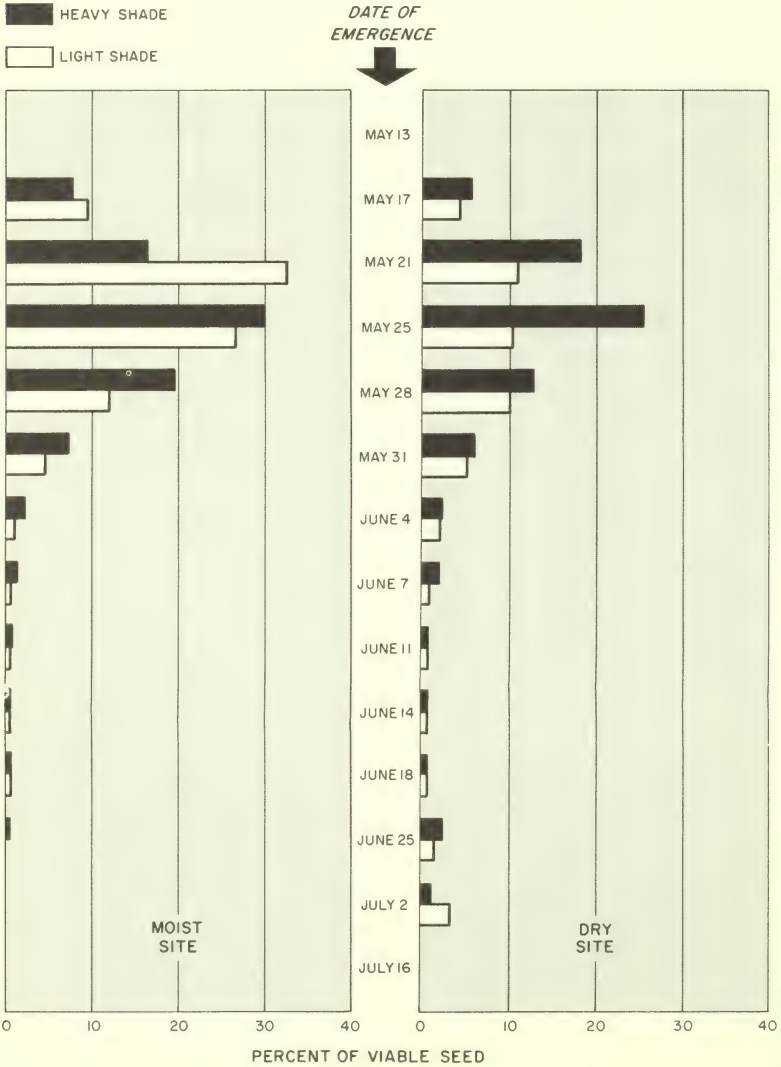

Figure 2.—Periodic seedling emergence as influenced by planting site and shade intensity.

Time of Emergence

The first seedlings appeared in mid-May, and by the end of the month 96 percent of the total emergence had occurred. Peak emergence occurred May 21 on the lightly shaded plots and May 25 on the heavily shaded ones (fig. 2).

These differences are the logical results of limiting environmental factors. In early May the soil moisture at both planting sites was near field capacity, and it was cold. On the moist site, seedling emergence did not occur until the soil began to dry and become warmer. Under the heavy shade, emergence was retarded, probably because of the cooler temperatures here.

On the dry site the soil dried rapidly, particularly at and near the surface. By the time temperature no longer limited germination, moisture on the lightly shaded plots was very likely inadequate. This resulted in an early peak emergence with a gradual decline in emergence as conditions (temperature and moisture) during the following 10 days became progressively less favorable. Under heavy shade, cooler moister conditions prevailed, and the emergence pattern was like that on the moist-site plots.

Seedling Survival

Seedling survival during the first growing season was uniformly good; of all the seedlings that emerged, 76 percent were alive at the end of October. Survival did not differ significantly among sites and treatments.

Apparently the variables of shade and site were important primarily during the critical period of germination and seedling emergence. After emergence had occurred, mortality was essentially similar regardless of these variables.

Seedling losses were related to the date of emergence. The later the emergence date, the more likely that mortality would be high (fig. 3). The seedlings emerging before May 26 averaged less than 20 percent mortality, but those emerging in late May and in June suffered much greater losses and averaged more than 60 percent mortality by the end of June.

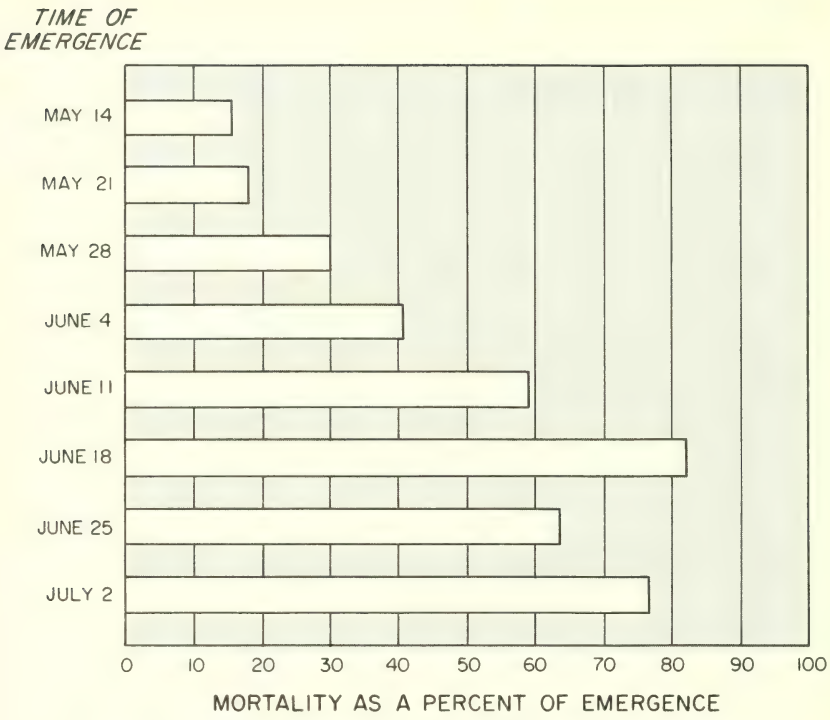

Figure 3.—Seedling mortality during first growing season as related to time of emergence.

There are several possible reasons for this rapid increase in mortality. (1) Weather conditions became less favorable as the season progressed, and losses from heat and from lack of moisture increased. (2) Those seeds occupying the more favorable microsites germinated earlier, but those situated under less favorable conditions tended to germinate late. And (3) germinative vigor may have been greater among the seedlings that emerged early in the growing season. Spurr (*1944*) found that the largest white pine seeds germinated first and that seedlings from these seeds survived better than those from the smaller seeds.

Regardless of the cause of mortality, survival was much poorer among seedlings that emerged in late May and in June. However, the overall effect of late emergence on seedling survival

was small because most of the seedlings had emerged before that time.

Causes of Mortality

The two most important causes of mortality were failure-to-establish and damping-off. The differences associated with site determined which of these causes would be preeminent (fig. 4). On the dry site, failure-to-establish accounted for 60 percent of all losses; on the moist site, damping-off accounted for 66 percent of all losses. Seedlings of the five seed sources did not differ in their susceptibility to these and other causes of mortality.

Failure-to-establish occurs when a seed germinates on or near the surface and the root tip is unable to penetrate to a moisture supply in the soil before the root dries out and dies. The direct cause of such mortality is lack of sufficient moisture, but this lack of moisture is frequently complicated by soil crusting or compaction, which acts as a barrier to root penetration. Although

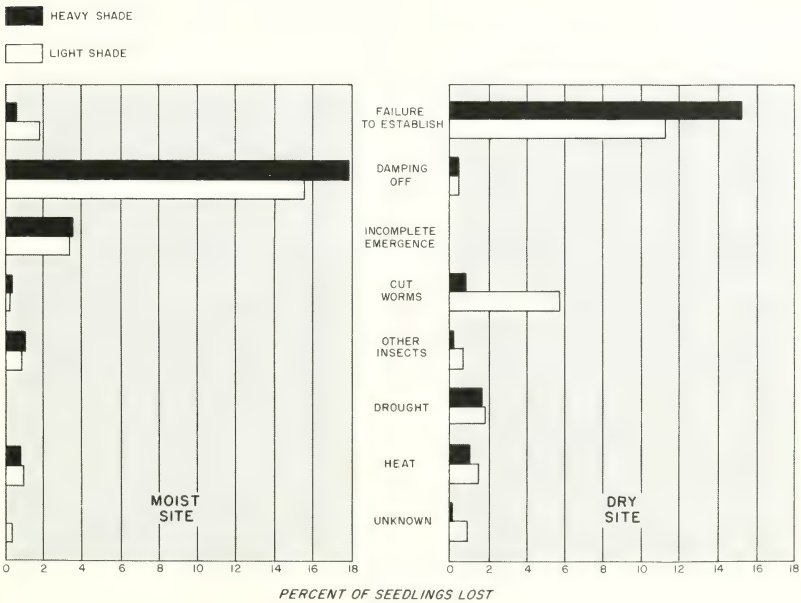

Figure 4.—Seedling mortality, by causal agents, in the first growing season.

this type of mortality is closely related to drought and is most common on dry sites, it differs from true drought mortality in that it can be overcome by planting the seed deeper.[3]

The failure-to-establish losses were low on the moist site, particularly on those plots under heavy shade. This was due to the better moisture supply, which enabled almost all seedlings to become established. On the dry site the failure-to-establish losses were most numerous on the heavily shaded plots. This was a reflection of the transitory nature of adequate surface moisture. Seeds exposed on the surface under light shade generally did not germinate, whereas many similarly placed seeds under heavy shade did germinate but then died before the root could reach moist soil.

Losses caused by damping-off fungi were closely related to planting site. The losses were negligible on the dry site and relatively high on the moist site. The high mortality on the moist site is believed to reflect not only the continuously moist conditions, but also the higher pH (about 6.0) of the Sutton loam. Both of these conditions would favor the development of damping-off fungi.

Other relatively minor causes of mortality were incomplete emergence, cutworms, drought, and heat injury.

Incomplete emergence[4] occurred only on the moist site where soil strength was sufficient to resist extraction of the cotyledons.

Cutworms were most damaging on the dry site, particularly in the lightly shaded plots. The heavy shade cloth very likely was a physical barrier to the movement of these larvae and may have been responsible for the reduced damage under that condition.

Drought losses did not occur on the moist site and were

[3] As noted earlier, our planting procedure was to press the seed into the soil surface and then cover it with 1/3 inch of loose soil. During the winter, some washing and frost-heaving occurred; and in May approximately 20 percent of the seeds were exposed. Had the seeds been planted deeper, the failure-to-establish losses almost certainly would have been reduced; on the other hand, had the seed been sown on the surface with no soil covering, the losses would have been much greater.

[4] Incomplete emergence occurs when the seedling hypocotyl emerges in the normal manner but is unable to extract the cotyledons from the soil and become erect. The buried cotyledons decay and the seedling dies.

minor even on the dry site. This mainly reflects the favorable periodicity and volume of rainfall during this particular growing season — 1962.

Heat injury caused minor losses under all treatments but was most damaging on the lightly shaded, dry-site plots. Small pieces of dark-colored organic matter were almost always in direct contact with the stems of injured seedlings and caused a lethal buildup of heat.

SUMMARY

Five white pine seed lots, collected locally over a range of soil drainage conditions, were sown on two planting sites (dry and moist) under light shade (85 percent of full light) and heavy shade (40 percent of full light) to test the effects of planting site and shade on seedling emergence and seedling survival.

Local seed source had no significant effect either on emergence or on survival in the first growing season.

The modification of the seed-seedling environment induced by heavy shade tended to overcome the unfavorable conditions of the dry planting site. Moisture was conserved at and near the soil surface, and the increase in moisture greatly increased seedling emergence. On the moist site, where lack of moisture was not a limiting factor, heavy shade slightly reduced seedling emergence.

Total seedling survivals were about equal among sites and shade treatments, but seedling losses due to each of the two major causes of mortality — failure-to-establish and damping-off — were strongly influenced by the site and the shade treatment. Almost all the losses caused by damping-off fungi occurred on the moist site. Nearly all the failure-to-establish mortality occurred on the dry site, particularly on plots under heavy shade where conditions on the soil surface were temporarily favorable for germination of seeds, but were of too short duration to allow seedling establishment. Other causes of seedling mortality were minor.

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DROUGHT RESISTANCE OF ROOTS of white ash, sugar maple, and red oak

by Johnson Parker

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U.S. FOREST SERVICE RESEARCH PAPER NE-95
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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INTRODUCTION

IN the northeastern United States, sugar maple (*Acer saccharum* Marsh.), white ash (*Fraxinus* americana L.), and red oak (*Quercus rubra* L.) are afflicted by dieback and decline diseases. The causes of these conditions have been discussed much in recent years, and the general consensus now is that one or more stress phenomena initiate them. Defoliation by insects is believed to be a primary factor in a decline of forest stands of sugar maple (called "maple blight" by *Giese et al. 1964*), and in the decline and mortality of red and scarlet oak (*Staley 1965*). Climatic factors too, especially drought, appear to play an important role in many of these diseases (*Westing 1966*).

It was suggested many years ago that drought alone might be the cause of certain diebacks and declines (*Balch 1927, Coover 1930*), particularly after the severe drought of the early 1930's (*Spaulding and Hansbrough 1935, Spaulding 1946, McIntyre and Schnur 1936; Parker 1965*). A more recent series of studies has given additional evidence that water deficiencies are important in the dieback and decline diseases (*Staley 1965, Hibben 1962, Ross 1964; Sinclair 1964*).

Although these recent studies have correlated periods of disease with periods of reduced precipitation, few researchers have

attempted to measure either the resistance of tree tissues to desiccation or the ability of tree roots to retain moisture (*Stocker 1956 and Sullivan and Levitt 1959*).

Of the various organs of the tree, roots seemed most to deserve study. First, because there is evidence that in some of the dieback diseases the roots appear to be affected before the tops (*Greenidge 1953*). And second, because there have been suspicions for some time that roots are killed during drought periods because of the impairment of their absorptive capacity. Such impairment might result from plugging of the xylem with gums or bacterial clots, or from direct desiccation of rootlets.

The question then arises as to the relative drought resistance of roots of different tree species. Two aspects of resistance seem important: the ability of living root cells to withstand low moisture levels (desiccation resistance), and the tendency for whole root segments to retain water under extremely dry soil conditions.

A study was made to determine (1) the relative levels of desiccation resistance in roots of white ash, sugar maple, and red oak and (2) the relative rates of water loss through the root bark.

METHODS AND MATERIALS

Trees used in this study were growing in two similar forested areas in southern Connecticut. These areas bore overstories composed of various species of oak, maple, ash, and birch, and had understories of such species as wild cherry and dogwood.

Ten root segments, 8 to 10 cm. in length and 1 to 2 cm. in diameter, dug from the upper 0.3 m. of soil about 1 m. from the bole, were collected from three individual trees of each of the three species. Roots of this size were selected because in some studies they accounted for most of the water absorbed (*Kramer and Bullock 1966*). Segments were kept overnight in plastic bags at 4.0°C. Experiments were then performed to determine desiccation resistance of cells and transpirational water loss via bark.

Desiccation Resistance

Root segments were collected in December 1965, April 1966, and August 1966. From each group of ten segments collected, three were selected at random. From each of these three, 16 thin (about 25 μ) tangential sections were made of the inner bark with a single-edged razor blade. These sections were dipped in tap water according to the procedure of Sullivan and Levitt (1959), and were exposed to one of four relative humidities (RH's) for 24 hours.

The 16 sections from each segment were divided evenly among four humidity chambers (1-quart bottles), each of which possessed a different RH as described below. With three different segments supplying three bottles held at one particular RH, and each of these three segments being used to make sections for four different bottles, this may be summarized as 3 segments x 4 RH x 3 species x 3 replications — a total of 108 bottles.

In the December experiment, the four RH's were maintained at 89, 95, 97, and 99 percent by using 30-ml. quantities of sucrose solutions of 2.0, 1.5, 1.0, and 0.1 M. at about 22°C. In the April and August experiments, 85, 90, 95, and 100 percent RH's were obtained by using 2.2, 1.9, 1.1 M. sucrose solutions and distilled water, respectively, at 22°C. to 26°C. RH values were verified before beginning the experiments by using the appropriate relative humidity probe inserted through a rubber stopper fitted tightly to a hole in the screw-cap top (fig. 1). The probe connected to a strip recorder.[1]

Sections were transferred with an artist's paint brush to the bottoms of 50-ml. beakers inverted in the widemouth bottles that contained the sucrose solutions.

After sections were exposed to the various humidities for 24 hours, measurements of viability were made by soaking sections for 1 hour in an aqueous solution of 12 ppm. neutral red containing 0.1 N. of $CaCl_2$. (Vacuoles of living cells absorb and hold the dye; dead cells do not absorb the dye or do so

[1] The narrow-range "Hygrosensor" probes and the strip recorder, Model 15-4050E, were manufactured by Hydrodynamics, Inc., Silver Springs, Md. Mention of a particular product should not be taken as an endorsement by the Forest Service or Department of Agriculture.

Figure 1.—A typical humidity chamber with its inverted beaker, solution, and root sections on the beaker. A humidity probe for testing relative humidity is also shown in the chamber.

only weakly.) Sections were then transferred to a slide, mounted in a drop of water and examined for viability under the microscope at 100X. Counts were made of cells in the area delineated by the field of an ocular micrometer and the percentage of living phloem ray cells for each was calculated. Observations were limited to ray cells because they comprised a large component of the living root tissues, were homogeneous, large in size, and of a regular pattern that facilitated measuring.

Water Loss through Root Bark

The rate of water loss by transpiration from exhumed root segments was determined in two experiments. The first, performed in June, utilized roots from one locality; the second, carried out in August, utilized roots from a similar area 30 miles distant. Segments were selected as before (three roots from each of three trees for each of the three species) and washed free of loose soil. After the segments had drained for 15 minutes and their severed ends had been coated with melted

paraffin to prevent water loss, they were kept under room conditions of temperature and RH (22°C., about 60 percent RH in June; 22°C. to 26°C., about 75 percent RH in August). Weighings were made at the intervals shown in the results. Both the fresh weight and oven-dry weight (105°C. for 48 hours) were used as bases for calculation of water loss.

RESULTS

Desiccation Resistance

Viability of cells subjected to the various RH's in different seasons increased from nearly zero at 89 to 90 percent RH to a maximum at 95 to 100 percent RH (fig. 2). It can be seen in these three graphs that there are, in some cases, apparent differences between certain species in their viability levels. However, considering all three experiments together and considering

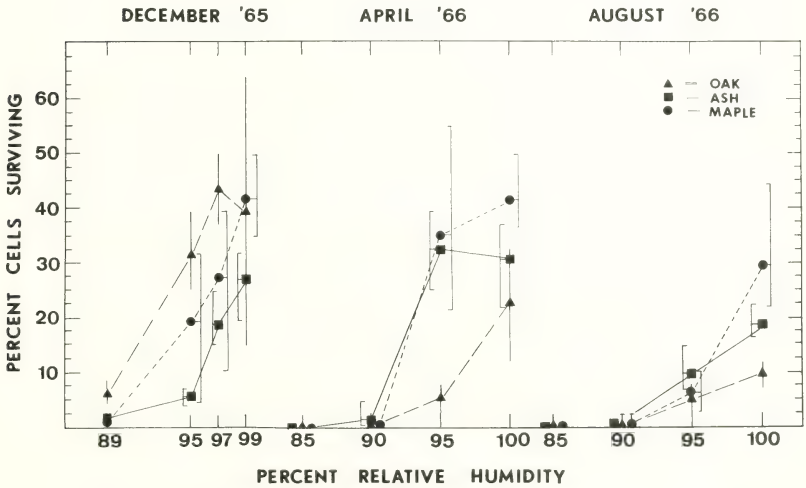


Figure 2.—Effects of 24 hours of dessication on thin sections of root bark kept at various relative humidities in three experiments. Viability as percentage of cells retaining neutral red per total cells counted is plotted for the three species over the various relative humidities. Each point is the average of three measurements of three roots from the same tree. Vertical lines indicate limits of data scatter.

the scatter in the data (the limits of which are shown on the graphs), I found no statistically significant differences in desiccation resistance among species.

Some indication of seasonal differences can be seen by comparing the three graphs in figure 2. In general, there appeared to be a decline in viability at the optimum RH (99 or 100 percent) from December to August.

Root Transpiration

Maple root segments dehydrated more rapidly in both experiments than did those of the other two species (fig. 3 and 4). Since dry weight is often considered a more consistent basis for comparison, results were based on dry weight. An analysis of variance of the data for the fifth day in each experiment showed that there were significant differences among species at the 5-percent level, but not at the 1-percent level. Water content of maple was significantly different from that of either ash or oak. These last two did not differ significantly from each other. Maple reached a state of equilibrium after about 7 days but the other

Figure 3.—Water content of whole-root segments as percentage of dry weight is plotted over time since start of experiment. Each point represents the average of nine roots. Data of North Madison, Conn., June 1966.

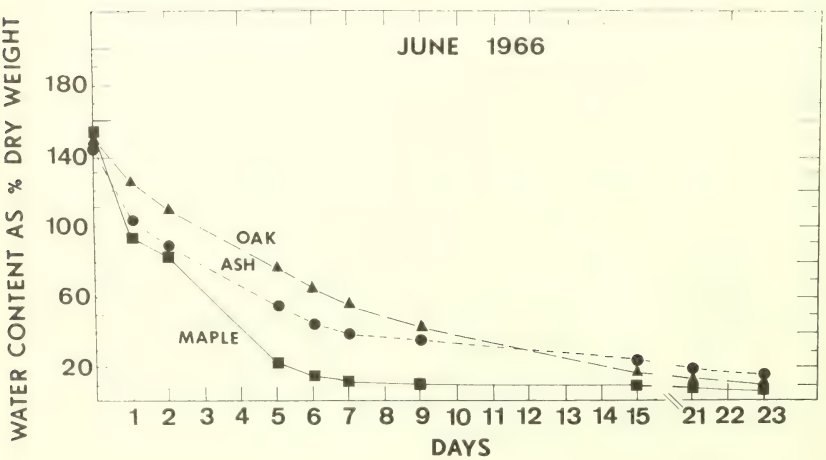
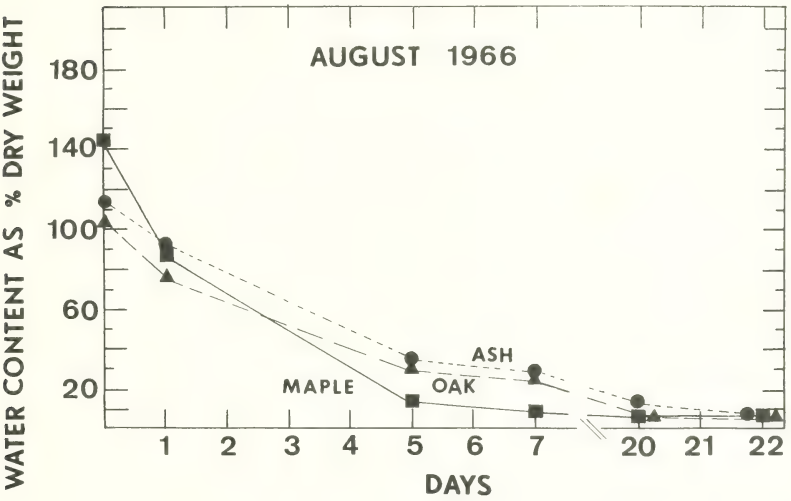


Figure 4.—Water content of whole root segments as percentage of dry weight is plotted over time since start of experiment. Each point represents the average of nine roots. Data of Haddam, Conn., August 1966.



two species continued to transpire appreciably after this. Eventually, water content of all three species fell to the same level (figs. 3 and 4).

DISCUSSION

The cells of the inner bark of the three species studied would not seem to possess any usually great resistance to the effects of a lowered moisture content. At least, their levels of survival compare closely to those of leaves of two species of oak (*Sullivan and Levitt 1959*). It would not be surprising then, that roots of the three species studied here would be injured during a protracted drought.

Under severe drought conditions, water loss by transpiration from the roots into the soil atmosphere could occur under certain soil conditions (*Slatyer 1956*). If root transpiration does occur under very dry soil conditions, the tendency of whole roots to retain water, as by means of heavily suberized outer

layers, might be of importance to survival. Certainly maple roots appeared to lose water by bark transpiration more rapidly than did roots of ash or oak. This might help to explain why sugar maple is generally less likely to survive on dry soil than the oaks. On the other hand, although maple roots transpired water more rapidly than did those of ash, it would be difficult to say, based on field observations, that white ash is more drought resistant than sugar maple.

The differences observed in root transpiration might indicate, too, that similar differences exist among these species in their rates of water absorption. Preliminary experiments indicate that dry maple roots absorb water more rapidly than do those of the other two species.

There are, of course, other differences among these species that might influence their drought resistance. It was observed in digging the roots for these experiments that the surface roots of oak angled downward at about 20 degrees from the horizontal, while the "ropelike" (*terminology of Lyford and Wilson 1964*) surface roots of maple and ash remained near the surface throughout their lengths. While there is mention in the literature of the relatively great depth of oak roots as compared with some other common trees (*Weaver and Kramer 1932, Brinkman 1957*), root depth varies greatly with soil characteristics and general rules are difficult to make. Biswell (*1935*) described a red oak 6 years old with roots 7 feet deep, while sugar maple 10 years old had roots to 10 feet. This is one of the few positive comparisons given in the literature for red oak and sugar maple trees older than seedlings and is, in itself, poor proof of any advantage of oak over maple.

■

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OAK SOIL-SITE RELATIONSHIPS
in the Ridge and Valley Region of West Virginia and Maryland

by Harry W. Yawney
G. R. Trimble, Jr.

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INTRODUCTION

A MAJOR FACTOR in the success of any forest-management program is the ability of the forester to evaluate forest areas and to delineate them into appropriate site-quality classes. It is mainly site quality that determines the growth potential of trees, and site also affects species composition and timber quality. For these reasons, a knowledge of site quality is basic in making decisions about management systems and stand-treatment priorities.

The most logical expression of site quality is a measure of the stand produced by the desired species on that site. However, for this measure to be reliable, the species must be present on the area in undisturbed stands that utilize the site completely. But too often these conditions are not met.

Many site studies made in the past 20 years have shown that, in the absence of suitable stands, site quality in terms of site index can be evaluated through the interpretation of soil-site factors found to be related with tree growth. This paper reports on such a soil site study made of five important oak species—red, scarlet, black, chestnut, and white oak — on upland sites in the Ridge and Valley Region of northeastern West Virginia and western Maryland (fig. 1).

Figure 1.—The portion of the Ridge and Valley Region covered by this study, and the location of the oak site plots.

PREVIOUS STUDIES

Soil-site studies made in various parts of the northern red oak range have established the importance of physiographic features and soil characteristics for predicting oak site quality.

The most pertinent of these for our study was made by Trimble and Weitzman (*1956*) in the Mountain area of West Virginia and Maryland to the west of the Ridge and Valley Region. They found that oak site index was closely related to aspect, position on the slope, slope percent, and depth of soil to bedrock. The northeastern slopes were between one and two 10-foot site-index classes higher than the southwestern slopes. Site index also improved with increasing distance from ridge top, decreasing slope percent, and increasing soil depth. In a

re-analysis of the data, Trimble (*1964*) was able to show that soil depth could be eliminated from the prediction equation without appreciably affecting the multiple regression correlation coefficient or the accuracy of the estimated site index. The elimination of soil depth was possible because of the relationship of soil depth to slope position and slope percent.

In the Arkansas Ozarks, Arend and Julander (*1948*) showed that oak site indexes varied with the depth of the soil to unconsolidated parent material, slope position, and aspect. In addition, they found that productivity was influenced by the parent material: the best sites occurred on soils derived from calcareous materials, the poorest on soils developed from sandstone and shale. Yawney (*1964*) also showed that in West Virginia oak site quality generally was better on a limestone soil — Belmont silt loam — than on sandstone and shale soils of similar texture.

Einspahr and McComb (*1951*) demonstrated in northeastern Iowa that site index improved as the soil depth increased, as the texture changed from sand or loamy sand to silt loams of good structure, and as the aspect changed from southwest towards northeast. Slope percent was shown to be significant, but only on the southern and western aspects. In southeastern Ohio, Gaiser (*1951*) reported that site indexes of white oak were influenced by slope position, aspect, and thickness of the A horizon. Gysel and Arend (*1953*) concluded that oak yields in southern Michigan were related to subsoil texture, slope position, and steepness of the slope.

Doolittle (*1957*) found a strong relationship between the site index of scarlet and black oak and the depth of the A horizon. This single variable accounted for 91 percent of the variance in site index. The percent of sand in the A horizon and the slope position were also significant variables. Although aspect had a definite effect on site index when considered alone, it was not significant in the presence of the other variables because of correlations with them.

Carmean (*1961*), examining the relationship of soil type and site index of black oak in southeastern Ohio, found that, because

of the extreme variability in site index, soil type alone could not be used to estimate sites accurately. He concluded that if soil taxonomic units are to be useful, either they must be refined or they must be subdivided into phases based on the specific soil and topographic factors that are closely related to forest site quality. The soil and topographic factors he found important for estimating site quality were depth of the surface soil, subsoil texture, subsoil stone content, aspect, slope position, and slope steepness.

Studying mixed oaks, yellow-poplar, and shortleaf pine on upland sites in the Virginia-Carolina Piedmont, Della-Bianca and Olson (*1961*) found that the major portion of the variance in tree height was accounted for by stand age. In contrast to numerous investigators elsewhere, they found only weak relationships with topographic and soil variables and concluded that this was due to the size of the geographic area and the large number of soil types included in their study. They further concluded that accepted techniques for identifying and measuring soil and other site factors may not be precise enough for the conditions encountered.

In addition to the site factors — slope position and the percent of clay in the surface horizon — McClurkin (*1963*) found it necessary to include basal area and stand age to arrive at a workable prediction equation for white oak in northern Mississippi and western Tennessee.

STUDY AREA

The topography of the Ridge and Valley Region is unique: a series of almost unbroken, long, parallel mountains oriented in a general northeast-southwest direction. The slopes are steep, rough and rocky, rising to an average elevation of 1,500 feet above the broad intervening valleys. Rock outcroppings are primarily sandstone or bands of shale, the latter being most common on the lower slopes. Limestone formations are found only in localized areas.

The sandstones and interbedded shales give rise to a variety of soil types and conditions. Soils on the ridge tops are generally shallow and coarse-textured, and they tend to be excessively drained. Textural composition and internal drainage are more favorable over a major part of the slopes, but towards the bottom, where the slopes become less steep, there is often a transition towards imperfectly drained soils. Here, in many places, fragipans have developed within the first 24 inches.

Precipitation over this part of the region averages about 35 inches annually and ranges from 30 inches in the south to 38 inches in the north. Based on 30 years of record, approximately 20 inches fall from April through September. Temperatures in this 6-month period average 66°F., and droughts of varying duration in midsummer and late summer are not uncommon. The frostfree growing season is about 160 days.

In the Ridge and Valley Region, the oaks are almost universally the dominant species on the upland sites. One or more oak species, either in pure stands or in mixture with other species, occur in all situations from the bottom of the slopes to the ridge top. On the main slopes and ridges, various oak types are represented by northern red oak (*Quercus rubra* L.), scarlet oak (*Q. coccinea* Muenchh.), black oak (*Q. velutina* Lam.), chestnut oak (*Q. prinus* L.), and white oak (*Q. alba* L.). Frequently pitch pine (*Pinus rigida* Mill.) and Virginia pine (*P. virginiana* Mill.) are strong components along with red maple (*Acer rubrum* L.), several hickories (*Carya sp.* Nutt), and black gum (*Nyssa sylvatica* Marsh). The species composition becomes more diverse on the lower slopes and in the shallow ravines with the integration of white pine (*Pinus strobus* L.) either as scattered individuals or in patches, yellow-poplar (*Liriodendron tulipifera* L.), basswood (*Tilia americana* L.), white ash (*Fraxinus americana* L.), and sugar maple (*Acer saccharum* Marsh.).

STUDY METHODS

In an effort to shortcut the work, we first attempted to use the oak site-index prediction equation developed by Trimble and Weitzman (*1956*) for the Mountain Province that borders our study area on the west. Site indexes estimated by their equation were compared with plot site indexes determined from tree measurements.

The rationale for this approach was the similarities of the soils sampled in both regions. Not only are texture, drainage, and parent materials similar, but the geologic series are the same. However, there are differences between the two regions in topographic configuration, elevation, and climate. We expected that an analysis of the Trimble and Weitzman equation would reveal one of three things, depending upon the magnitude and distribution of the differences between the two site-index values: (1) that the Trimble and Weitzman equation could be applied directly; (2) that this equation could be adjusted to cover the Ridge and Valley Region; or (3) that it would be necessary to develop a separate prediction equation for the Ridge and Valley Region.

The field procedures in this study followed the methods of Trimble and Weitzman (*1956*). The selection of the plots was restricted to upland even-aged oak stands occuring on medium-textured, well-drained soils derived from sandstone and shale parent material. Plot size was variable but, to minimize soil and topographic variation, did not exceed 1/5 acre.

The independent variables contained in the Trimble and Weitzman equation — aspect, slope position, percent slope, and soil depth — were carefully measured, and, following the appropriate transformation, estimated site index was calculated for each plot using their equation:

$$\text{Log site index} = 1.9702 - 0.0618X_1 + 0.0012X_2 - 0.0020X_3 - 0.1509X_4.$$

Measurement of each variable was made as follows:

Aspect (X_1). — Orientation of the slope measured with a

hand compass facing down the slope and across the plot (transformed as the sine of the azimuth from southeast + 1).

Slope position (X_2). — Distance of the plot from the ridge expressed as a percent of the total slope length.

Percent slope (X_3). — Steepness of the slope over a distance of 2 chains across the plot and expressed as a percent.

Soil depth (X_4). — Average depth determined from observations made in a pit at the plot center, and from measurements made with a soil probe (*Yawney 1959*) 30 feet on either side and above and below the plot center. The soil pits were dug either to bedrock or to a depth of 4 feet. Where it was possible, the probe was used in the pits to record additional soil depths to a maximum of 6 feet. However, in the above equation 3.5 feet was the maximum soil depth used to predict site index (transformed as the reciprocal of soil depth).

As shown later in the analysis, the Trimble and Weitzman equation was tried in the Ridge and Valley Region on the basis of 30 plots. However, the study was later expanded to include a total of 57 plots. From the start, an effort was made to sample the full range of prevailing conditions. The number of plots in each site-class as well as their distribution by topography and soil depth is given in table 1.

The soils were described by soil scientists of the Soil Conservation Service, U. S. Department of Agriculture.[1] The most frequently sampled soils were either the channery or stony phases of the Laidig, Dekalb, Lehew, Calvin, and Mench series. Provisions for laboratory analysis of soil samples were not included in this study. Soil texture was determined by feel at the pit. A field colormetric kit was used to record reaction of the various horizons.

[1] The authors are indebted for the soils description work done by John L. Gorman and William Curry, soil scientists, Soil Conservation Service in West Virginia; and to Kenneth M. Stone, soil scientist, Soil Conservation Service in Maryland. Also, appreciation is expressed for the assistance provided by State County Foresters Leon Wilson of West Virginia and Harry M. Hartman of Maryland, in locating the study plots.

Table 1.—Distribution of the 57 study plots by site class, topography, and soil depth

(Number of plots)

Site-index class	Aspect			Slope position (distance from ridge over total slope length, in percent)				Slope steepness (percent)			Soil depth (feet)				Number of plots in each site class
	NE	SE & NW	SW	0-25	26-50	51-75	76-100	0-20	21-40	41+	1.5-2.4	2.5-3.4	3.5-4.4	4.5-6.0	
50 (45-54)	1	7	3	4	4	2	1	3	7	1	3	—	3	5	11
60 (55-64)	3	21	4	12	8	7	1	10	17	1	1	5	10	12	28
70 (65-74)	2	12	1	—	5	6	4	4	8	3	—	2	3	10	15
80 (75-84)	1	2	—	—	1	2	—	1	2	—	—	—	1	2	3
Totals	7	42	8	16	18	17	6	18	34	5	4	7	17	29	57

Five oak species, which occurred on the plots in varying proportions, were sampled in this study: red, scarlet, black, chestnut, and white oak. On each plot, tree heights and ages were taken on 5 to 10 dominants and co-dominants, and site indexes were determined by referring to the curves developed by Schnur (*1937*). Height measurements were made with a Spiegel-Relaskop. Total ages of the trees were obtained by adding 3 years to core samples obtained at diameter breast height. Acceptable variation in age between sample trees on any plot was limited to 10 years, and the average tree age of the study plots ranged from 33 to 73 years.

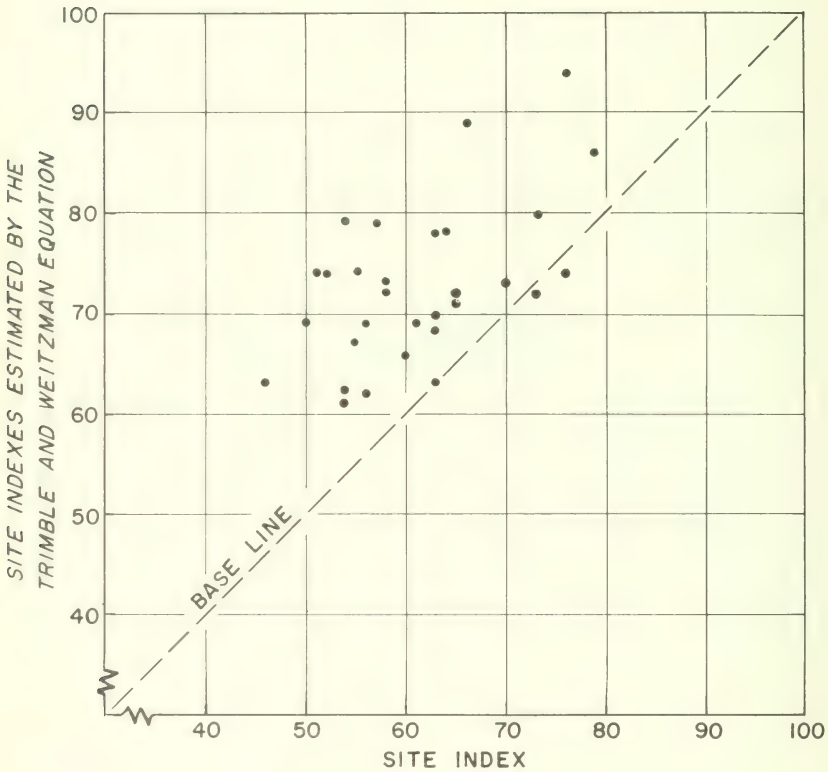
ANALYSIS AND RESULTS

The fit of the Trimble and Weitzman equation on the oak sites in the Ridge and Valley Region is graphically illustrated in figure 2. With the exception of three plots, their equation consistently overestimated site index by 3 to 25 feet. Had there been any semblance of fit, the points would have been about equally distributed above and below the 45-degee base line. Estimated and measured plot site indexes were treated as paired values in a t-test analysis, and differences between them were found to be significant beyond the 1-percent level.

The possibility of adjusting the predicted site-index values for the conditions in the Ridge and Valley Region was explored by calculating a regression line for the distribution shown in figure 2. The correlation coefficient that resulted is 0.562, and this is significant at the 1-percent level. Thus, correlation is found to exist but is somewhat lower than that desired to permit extension of the Trimble and Weitzman equation. However, the significant correlation coefficient did indicate that one or more of the site factors in their equation was important for predicting oak site index in the Ridge and Valley Region.

The remaining alternative, then, was to develop a separate site-index prediction equation for the Ridge and Valley Region. This necessitated sampling additional plots, and 27 plots were added to the study to make a total of 57.

Figure 2.—Comparison of site indexes predicted by the Trimble-Weitzman equation with site indexes determined from Schnur's curves for the plots in the Ridge and Valley Region.



Ten topographic and soil variables were analyzed by multiple regression to determine their usefulness as predictors. The ten variables are as follows: aspect, slope position, length of slope above the plot, percent slope, elevation, pH of the A_2 horizon, soil depth to a maximum of 6 feet, and the thickness of the A, A + B, and C horizons. In addition to these, selected interactions were also tried as independent variables.

The association of stand age and site index was also examined. From a scatter diagram a strong negative relationship was evident, and as a result average height was included with site index as a second dependent variable in the analysis.

Utilizing the 7090 IBM Computer, we were able to compute coefficients of multiple determination, R^2, for a large number of equations. This phase of the analysis represented a screening in which each independent variable, alone and in combination with other independent variables, could be evaluated in light of its contribution to the R^2. Transformations for specific variables were also screened where deviations from linearity were suspected, including the dependent variables that were transformed by the use of logarithms.

After a careful examination of all possible combinations, five independent variables emerged as the most efficient combination of components to retain in the final regression. These were: stand age, aspect, slope position, thickness of the A + B horizons, and pH of the A_2 horizon. All five variables were found to be significantly related to both site index and average tree height. However, the analysis showed that average tree height was better expressed as a function of the independent variables than was site index. The final equation relating age and the soil and topographic variables to tree height is:

$$\text{Logarithm of average tree height} = 1.8807 - 9.7538X_1 - .0336X_2 + .0006X_3 - .5071X_4 + .0261X_5$$

where the independent variables are expressed as:

X_1 = the reciprocal of stand age (1/stand age).

X_2 = aspect (the sine of the azimuth taken from SE and adding 1).

X_3 = Slope position (determined as the percent distance from the ridge line in relation to the total length of the slope).

X_4 = the reciprocal of the thickness of the A + B horizons in inches (1/A + B horizons).

X_5 = pH of the A_2 horizon

The significance of the partial regression coefficients and the amount of variance accounted for by each independent variable were determined (table 2). The multiple correlation coefficient for the equation is 0.824, and the standard error of estimate is $\pm$ 4.7 feet at the average height of 60 feet.

Table 2.—Independent variables and the amount of height variance accounted for by each in the equation

Variable	"t" values of the partial regression coefficients	Variance explained[1]
		(*Percent*)
Stand age	8.1229**	36.6
Aspect	3.9820**	8.1
Slope position	3.2447**	9.9
Thickness of A + B horizons	3.8907**	9.8
pH of the A_2 horizon	2.230*	3.5

[1] Determined as a ratio of the individual variable sum of squares and the total sum of squares.

* Indicates significance at 5-percent level.

** Indicates significance at 1-percent level.

Slight but significant correlations were noted between pH and slope position and between pH and stand age. The correlation coefficients were 0.278 and 0.274 respectively (significant at the 5-percent level). However, the relationship between pH and average tree height remained significant when the effects of slope position and stand age were removed.

The significance of pH cannot be explained because we did not make a chemical analysis of soil samples. The range of pH for the soils on the study plots was from 4.0 to 6.0. This range is within the limits of that generally accepted as suitable for hardwood growth *(Lutz and Chandler 1946)*. Rarely has pH appeared as a significant variable in other site studies. Thompson and McComb (*1962*) reported a significant correlation with site indexes of plantation-grown black walnut in Iowa. They were able to show that the relationship between pH and site index was in fact a reflection of calcium and potassium deficiencies.

As a predictor, the use of pH would be questionable in situations where the litter and humus layers have undergone a severe transition as in the case of heavy thinnings and on clear-cut areas. pH is not a stable variable and can be greatly influenced, especially in the surface horizons, by changes in stand condition.

Therefore it would be desirable to eliminate pH from the prediction equation. Without pH, the multiple correlation coefficient changes from 0.824 to 0.804, and the standard error of estimate is increased only slightly from ± 4.7 to ± 4.9 feet. The four-variable equation in the same order as before becomes:

$$\text{Log of average height} = 1.9964 - 9.0631X_1 - .0375X_2 + .0008X_3 - .5058X_4$$

Data for use as a field guide were computed with this equation (table 3). In the computations, 50 years was substituted for age (X_1), and only the three factors shown in the table need to be determined in field use.

The analysis also revealed the existence of several other relationships. A weak but significant correlation was found between soil depth measured to a maximum of 6 feet and stand height. Thickness of the A + B horizons revealed a much stronger relationship than total soil depth— probably because of greater measurement precision. With some soils, as in the Calvin series, total depth was difficult to determine because of the lack of a distinct boundary between the highly weathered shale parent material and the underlying bedrock.

Table 3.—Estimated site index of oak on medium-textured, well-drained sandstone and shale soils in the Ridge and Valley region of West Virginia and Maryland

Thickness A + B horizon (inches)	Slope position and aspect														
	Top (1 percent)			Upper (25 percent)			Middle (50 percent)			Lower (75 percent)			Bottom (99 percent)		
	SW	SE & NW	NE	SW	SE & NW	NE	SW	SE & NW	NE	SW	SE & NW	NE	SW	SE & NW	NE
6	45	49	54	47	52	56	50	54	59	52	57	62	54	59	65
12	50	54	59	52	57	62	55	60	65	57	62	68	60	65	71
18	52	56	61	54	59	64	56	62	67	59	64	70	62	68	74
24	52	57	62	55	60	65	57	63	68	60	66	71	63	69	75
30	53	58	63	55	60	66	58	63	69	61	66	72	64	69	76

There was an almost perfect inverse correlation between thickness of the C horizon and the combined depth of the A and B horizons. The correlation coefficient for this relationship was 0.994. However, the exceedingly high correlation shown here is misleading because a number of plots had soils that were in excess of the 6-foot maximum depth used in the analysis. Positive relationships also were observed between the depth of A + B horizons and the total soil depth, and between the depth of C horizon and the total soil depth. But their respective correlation coefficients, although significant, were only 0.417 and 0.321. The poor agreement indicated by the size of these coefficients emphasizes in part the difficulty of obtaining accurate total-depth measurements and the inadequacy of the arbitrary termination of solum thickness at 6 feet.

The analysis revealed that the length of the slope above the plot, which was considered as an alternative to slope position, was related to stand height, but not as strongly as was slope position.

No relationship was evident between the depth of the A horizon and stand height even though the depths of the A horizon ranged between 2 and 15 inches. However, this was not surprising in view of the nature of the root distributions observed. Generally, the major mass of fine roots was found to be evenly distributed throughout a depth that varied between 15 and 20 inches. The analysis bears out the observation that this root distribution occurred regardless of the depth of the A horizon.

Neither of the other two factors included in the analysis — percent slope and elevation — was significantly related to stand height.

DISCUSSION

The analysis of the data clearly shows that the oak site index prediction equation developed by Trimble and Weitzman for the neighboring Mountain Region cannot be extended without considerable loss in prediction accuracy, either directly or by adjustment, to include the oak sites in the Ridge and Valley

Region. In similar trials with longleaf and slash pine, Hodgkins (*1956*) failed to achieve good correlations between predicted and measured site indexes in southwestern Alabama with several equations developed in other geographic regions of the South.

The failure of the Trimble Weitzman equation to predict oak site indexes in the Ridge and Valley Region can most likely be explained by the climatic differences that exist between the two regions. Average monthly temperatures and precipitation through the growing season based on 30 years of record are shown in figure 3. Precipitation for the Ridge and Valley Region is approximately 35 percent less than for the Mountain Region. Monthly temperatures for this period in the Ridge and Valley Region averaged 3.4° F. higher than in the Mountain Region. The greater evaporation and transpiration potential indicated by the higher temperatures, combined with lower rainfall, no doubt alters the oak growth patterns from that predicted by the Trimble and Weitzman equation. An estimate of the effects of these climatic differences on growth can be gained from the site index comparisons in figure 2. The productivity of sites having the same soil and topographic factors is fully one site class lower in the Ridge and Valley Region.

The full impact of the precipitation patterns on the growth of oak in the Ridge and Valley Region cannot be fully appreciated without reviewing the work done by Tryon and True (*1958*) in nearby Pocahontas County, West Virginia. Their investigation dealt with reductions in annual radial increment of scarlet oak as related to rainfall deficiencies. This study covered the years 1949 to 1956. During this period, droughts were recorded in 1949, 1951, 1953, and 1955. The effect of these successive droughts was a general decline in the growth rates. Reductions in radial increment were shown to occur during the growing seasons after the drought years and were related to dry periods during the months of July to September of the previous year. The portion of the Ridge and Valley Region covered by our soil-site study was similarly subjected to the same repeated droughts, and the implication is that the oak in this area suffered the same growth losses.

Figure 3.—Comparison of average (1931 to 1960) monthly temperatures and precipitation during the growing season in the Ridge and Valley Region of West Virginia and Maryland and the neighboring Mountain Region of West Virginia.

Long-term precipitation records reveal that extended dry periods during mid-summer and late summer are not at all uncommon. It follows that the accumulative effect of the periodic soil-moisture deficiencies chronic to the Ridge and Valley Region is to alter the oak growth patterns from that observed in other parts of the northern red oak range.

SUMMARY

A soil-site study was made in the Ridge and Valley Region of northeastern West Virginia and western Maryland to evaluate the relationship between several environmental factors and the growth of oak trees.

As a first step, we determined whether or not an oak site index estimating equation previously developed in the Mountain Region immediately to the west was applicable or could be adapted to the Ridge and Valley area. Statistical analysis indicated that it could not be applied without a drastic reduction in estimation precision. This meant that a separate equation was needed. Such an equation was developed from data taken on 57 plots on well-drained medium-textured soils derived from sandstone and shale parent materials.

A large number of variables were examined to determine their relationships to both oak site index and average tree height. The analysis showed that the greatest possible amount of the variance observed in either site index or average tree height was accounted for by the same five independent variables. These are: stand age, aspect, slope position, thickness of the A + B horizons, and pH of the A_2 horizon. Because of greater estimating precision, the equation was developed on the basis of average tree height with the resulting multiple correlation coefficient of 0.824 and a standard error of estimate of $\pm$ 4.7 feet at the average tree height of 60 feet. Stand age was by far the most important single independent variable: it accounted for more than half of the total explained variance.

The data developed in this study made it possible to compare oak site indexes between the Ridge and Valley Region and the

adjoining Mountain Region. Site indexes were considerably lower in the Ridge and Valley Region for sites with similar soils and topographic conditions. These differences are attributed to the lower rainfall and higher growing-season temperature.

■

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Provisional
GRADE SPECIFICATIONS
For Hardwood Growing-Stock Trees

by Stephen G. Boyce
and Roswell D. Carpenter

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U.S. FOREST SERVICE RESEARCH PAPER NE-97
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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Provisional
GRADE SPECIFICATIONS
For Hardwood Growing-Stock Trees

GRADE SPECIFICATIONS ARE NEEDED NOW

THE YOUNG TREES that we see growing in our forests today are the trees that we must rely upon to supply our timber needs 25 years from now. We see plenty of these young trees. The question is: How well can we foretell what their quality will be when they mature?

High quality in hardwood trees is measured by the proportion of clear, sound wood that they contain. We can assume that only a portion of the young trees will grow into high-quality sawtimber trees. These will be needed for veneer logs, sawlogs, bourbon staves, handle bolts, and other products that require high-grade material. Those trees that do not grow into grade-1

trees will be used for crossties, pulpwood, and other products for which defect-free wood is not required.

The problem today is to identify those young trees that can be grown to provide the high-quality mature trees of the future. To do this, we need a set of technically sound and readily understandable and applicable specifications that forest managers can use to single out young trees according to their potential for yielding grade-1, grade-2, and grade-3 sawlogs at maturity.

To this end we have evolved a set of provisional grade specifications for hardwood growing-stock trees. Please note that these specifications are only tentative. They must be evaluated by examining the performance of graded trees for many years. As our experience increases, we can refine and modify the grade specifications. Meanwhile, tentative as they are, they provide a tool that we can use.

THE OPPORTUNITY

Today there is a shortage of the large, clear logs needed for fine veneer and high-grade lumber. This shortage is especially acute for select oaks, yellow birch, sugar maple, white ash, black cherry, black walnut, sweet-gum, and yellow-poplar. The supply of big trees from the original old-growth forests is nearly exhausted.

Our big opportunity is to make the best use of the small trees. Our hardwood timber, though smaller, is growing faster than it is being cut. Sixty percent of all forest growing stock of desirable commercial species is in small trees, 7 to 15 inches in diameter breast high (*10*).

Many of these young trees will die as insects, disease, fire, and competition exact their toll. Yet there are enough to provide the basic growing stock for millions of grade-1 hardwood trees. Our opportunity is to select and then to promote the young trees that have this potential.

Meanwhile we already know a lot about the growth of hardwood trees, the identification of defects from their indicators,

and the conformation of logs needed to satisfy the specifications of the Forest Service hardwood sawlog grades. We can compute the volume of lumber from logs and trees by lumber grade.

THE GRADE SPECIFICATIONS

Our grade specifications for growing-stock trees are correlated with the Forest Service grade specifications for hardwood sawlogs (table 1). Our specifications describe three basic grades for trees: growing-stock grade 1, growing-stock grade 2 and growing-stock grade 3. The grades are assigned according to the probability of a tree yielding a grade-1, grade-2, or grade-3 butt log when it reaches 16 inches d.b.h. A tree 16 inches d.b.h. is the smallest tree that will yield a 16-foot grade-1 butt log. We define our tree grades as follows:

- A grade-1 growing-stock tree has an 80-percent probability or better of yielding a grade-1 butt log 12, 14, or 16 feet long.
- A grade-2 growing-stock tree has less than an 80-percent probability of yielding a grade-1 butt log, but a 50-percent chance or better of yielding a grade-2 butt log.
- A grade-3 growing-stock tree has less than a 50-percent

Table 1.—Provisional grade specifications for hardwood growing-stock trees

Growing-stock grades	Grading factors						
	D.b.h.	Crown class	Length of butt log	Scaling deductions	Sweep, maximum	Lean, maximum	Surface defect indicators
	Inches		*Feet*		*Inches*	*Degrees*	*Number*
1	7-15	Dominants and codominants	12, 14, 16	Only sweep admitted	4	4	4
2	7-15	Dominants and codominants	12, 14, 16	Only sweep admitted	6	6	5-17
3	7-15	Dominants and codominants	12, 14, 16	Only sweep admitted	8	8	18-30

probability of yielding a grade-2 butt log, but a 50-percent chance or better of yielding a grade-3 butt log.

Trees are graded according to those factors that will limit the value of lumber products. The grading factors we used are as follows:

D.b.h. (Diameter Breast High)

A growing-stock tree is 7 to 15 inches d.b.h. The upper limit was set at 15 inches because trees 16 inches and larger can yield a grade-1 butt log, and tree grades can be applied to them (*8*). The lower limit of 7 inches d.b.h. was set for two reasons. First, the heart center (7) permitted in the smallest allowable grade-1 log has formed by the time the tree reaches 7 inches d.b.h. Second, the number of suppressed buds and epicormic branches decreases rapidly just before the tree reaches this diameter (*1*).

Crown Class

The opportunity for improving tree quality is greater with dominant and codominant trees than with those in the lower crown classes. Only dominant and codominant trees qualify for growing-stock grade 1 and grade 2. Grade 3 admits all crown classes.

Length of Butt Log

Characteristics of the lower 12-, 14-, or 16-foot log are used in the grading specifications. The butt log of hardwoods has the best potential for producing grade-1 logs in the shortest time (*1*). The butt log reaches grade-1 diameter requirements faster than upper logs because hardwood tree stems taper upward, and added diameter is essential to the increase in volume of clear wood. Second logs can qualify for grade 1 only when they reach 16 inches in scaling diameter. Grade-1 second logs demand trees of 22 inches d.b.h. or more. The growing-stock grade is assigned to each tree for the 12-, 14-, or 16-foot butt log according to its potential to yield a grade-1, grade-2, or grade-3 log.

Scaling Deductions

Growing-stock trees are chosen without any defects that will cause a reduction in gross log scale — except sweep. Trees with seams, cracks, splits, rot, and other features that indicate possible decay will not be considered. If admitted, these defects might well increase in time, and the percent deduction in the mature logs could exceed the total scaling deduction allowed in the Standard Hardwood Sawlog Grades.

Sweep

Sweep in a log causes a deduction from gross log scale when it exceeds the taper measurement for a given log. Growing-stock grade-1 trees are allowed to have up to 4 inches of sweep in the butt 12-, 14-, or 16-foot log; grade-2 trees are allowed up to 6 inches, and grade-3 trees are allowed up to 8 inches. These limits are slightly too large for grade-1 and grade-2 logs of the minimum 13-inch scaling diameter, but for logs 14 inches and larger they will fall well within the restrictions contained in the Standard Hardwood Sawlog Grades. Methods for computing log scale deductions for sweep are set forth in *A Guide to Hardwood Log Grading* (7).

Lean

Grade-1 growing-stock trees are allowed to have up to 4 degrees of lean ; grade-2 trees are allowed up to 6 degrees; and grade-3 trees are allowed up to 8 degrees. The effect of lean in a tree is not included in the Standard Hardwood Sawlog Grades as a degrading factor, yet the tension wood nearly always associated with leaning trees may reduce the utility of the wood for some uses. Trees that have less than 4 degrees of lean usually have little tension wood; however, those with 8 degrees of lean or more will have enough to affect the utility of the lumber (*2*, *9*). Thus the permissible lean for grade-1, grade-2, and grade-3 immature trees is limited to 4, 6, and 8 degrees, respectively.

Surface Defect Indicators

Surface features such as knots, birdpeck, insect signs, epicormic branches, adventitious bud clusters, and limbs indicate

log defects (*5*). And on trees 7 to 15 inches d.b.h. these defects will limit the length of clear cuttings in lumber sawed from most merchantable sawlogs. However, exceptions occur. For example, in black cherry, adventitious bud clusters and light bark distortions are admitted in the cuttings. This is done because the indicated small knots (1/8 inch), pith ray flecks, and gum spots are admitted in the designated clear cuttings as defined in the official lumber grading rules of the National Hardwood Lumber Association (*6*).

The presence of most defects in merchantable logs usually is signified by bark distortions and other surface indicators. But bark grows, so indicators lose their usefulness progressively; and in time the indicators may become buried under normal bark growth. It is not always possible to predict the loss of an indicator, the entrance or emergence of a grub, the growth of a new branch, or the feeding of a sapsucker. Changes in the number and location of defect indicators cannot be predicted. Thus, an element of chance is inherent in any system designed to predict future log grades for growing trees. Because of this element of chance, probabilities (table 2) are used to segregate trees for growing-stock grades rather than clear cuttings as for the sawlog grades.

From the Standard Hardwood Sawlog Grade Specifications, it is possible to count the number of defects that limit clear cuttings on the three best faces of the log (*3*) and to determine the probability of a given number of defects limiting these clear cuttings in relation to specified lengths. While developing these specifications (*11*), we found that logs could be grouped reliably according to similar lumber grade yields by combining the minimum length and the number of clear cuttings with the percentage of log length required in clear cuttings and applying this to the three best log faces. The same combining process is used to determine the grade of a board in grading hardwood lumber (*6*).

If we find one defect on one face of an otherwise clear grade-1 log, we cannot lower the log grade from 1 to 2. So, for

logs having 0 or 1 defect indicator and no other degrading features, the probability that these logs will qualify for grade 1 is 100 percent. However, two indicators can be so located that the log grade is 2 instead of 1. The probability that two defect indicators will have just the right position to place the log in grade 2 is less than 1 percent, and the probability is about 99

Table 2.—Probability of the butt 12-, 14-, or 16-foot log with various numbers of defects occurring in one of three standard sawlog grades and the relationship to growing-stock grades.[1]

Number of defects	Standard sawlog grade			Growing-stock grade
	1	2	3	
	Percent	*Percent*	*Percent*	
0	100.0	—	—	
1	100.0	—	—	
2	99.0	—	—	1
3	89.4	10.6	—	
4	80.7	19.3	—	
5	69.7	30.3	—	
6	58.9	41.1	—	
7	44.9	55.1	—	
8	30.2	69.8	—	
9	22.3	77.2	0.5	
10	17.9	81.0	1.1	
11	12.7	82.8	4.5	2
12	9.3	82.7	8.0	
13	6.5	79.5	14.0	
14	3.9	74.2	21.9	
15	1.3	69.7	29.0	
16	—	63.0	37.0	
17	—	55.5	44.5	
18	—	47.5	52.5	
19	—	40.0	60.0	
20	—	32.0	68.0	
21	—	25.0	75.0	
22	—	20.0	80.0	
23	—	14.0	86.0	3
24	—	9.0	91.0	
25	—	5.0	95.0	
26	—	1.0	99.0	
27	—	.5	99.5	
28	—	—	100.0	

[1] Table adapted from Boyce and Schroeder (*3*).

percent that an otherwise perfect log with two indicators will qualify for grade 1 (table 2).

If the two indicators are on the same face, they cancel out because three clear faces remain. If they are on different faces, only one affects log grade, and a choice remains for selecting the three best faces. The chance that both will occur in the same horizontal plane in the tree stem is very slim. Probabilities for 0 to 28 defect indicators were determined for 1,109 logs (*3*). These probabilities are shown in table 2.

As the number of indicators increases, the probability that a log will qualify for grade 1 decreases. Between 4 and 8 indicators, the addition of one more reduces the probability that the log will qualify for grade 1 by 10 to 15 percent. These numbers constitute the range of most rapid decrease for grade 1 and the most rapid increase for grade 2. These probabilities are determined from the log-grade specifications and not from differences among species. Changes in the log-grade specifications will alter these probabilities.

Grade-1 growing-stock trees have 80 percent probability or better of producing grade-1 butt sawlogs at maturity. Table 2 reveals that grade-1 growing-stock trees can have up to four surface indicators of defect limiting clear cuttings on the butt log when the tree is 16 inches d.b.h. Likewise, grade-2 growing-stock trees can have 5 to 17 indicators, and grade-3 trees can have 18 or more indicators.

SOME PRACTICAL APPLICATIONS

Hardwood sawlogs have a range of values extending all the way from that of the poorest grade-3 log up to that of the largest and best grade-1 log. For yellow birch this spread could make a difference of $240 per thousand board feet at present lumber prices. The yields of No. 1 common and better grades of hardwood lumber produce most of the value of hardwood sawlogs. The Standard Hardwood Sawlog Grades segregrate woods-run sawlogs into the three grades based on the

proportions of No. 1 common and better lumber present. Actually the log grades are best depicted as three bands with a small amount of overlapping at the boundaries between grade 1 and grade 2 and between grade 2 and grade 3 (*11*).

The accompanying yield tables are expressed in terms of percentage of each of the standard hardwood lumber grades (*6*) for each scaling diameter in each of the three sawlog grades. The growing-stock grades are also best depicted by the band concept, with a certain amount of overlapping at the two inner boundaries. Expected lumber grade yields now calculated for the growing-stock grades may be somewhat lower because each tree is graded on the probability that it will produce the same mature grade of log as now assigned to it. These expected yields can be computed by multiplying the probability numbers in table 2 by the appropriate percentage figures taken from the lumber grade yield tales (*11*).

The ranges of expected lumber grade yields for several common hardwoods at 16 inches d.b.h. are shown in table 3. These are minimum figures because they are based on the allowable scaling diameter, 13 inches, for grade -1 logs. Larger logs will produce higher yields because diameter is the most important factor that affects hardwood sawlog grades. And in a group of

Tables 3.—The ranges of expected yields of Number 1 common and better lumber from butt logs of growing-stock trees when 16 inches d.b.h. for some species.

Species	Growing-stock grades		
	1	2	3
	Percent	*Percent*	*Percent*
Yellow-poplar	51-49	44-23	20-18
Black oak	61-55	51-21	20-13
Red oak (upland)	58-54	51-24	21-9
White oak (upland)	55-51	48-23	20-9
Hard maple	60-55	52-25	23-14
Yellow birch	57-53	50-25	23-10
Sap gum	64-60	58-35	32-22

grade-1 logs, including logs with small, medium, and large scaling diameters, average yields of the better lumber grades will be higher because the yields from larger logs will raise the average for the smaller ones. Any examination of lumber grade yields, including those in table 3, demonstrates vividly the advantage that grade-1 growing-stock trees have over growing-stock trees of grades 2 and 3.

Growing-stock grades provide an effective means for using timber-stand-improvement operations for growing more grade-1 sawlogs. Obviously, grade 1 and grade 2 offer good opportunities to use timber-stand-improvement practices effectively and to return a profit on the investment. Let us consider a few likely applications of the growing-stock grades.

Say that a forest manager wants to increase the diameter growth of trees in an immature hardwood stand. He is willing to invest only in trees with an 80 percent probability or better of yielding a grade-1 sawlog upon reaching 16 inches d.b.h. He instructs his workers to choose for culture only dominant and codominant trees 7 to 15 inches d.b.h. with potential 12-, 14-, or 16-foot butt logs. These trees must show no evidence of defect that may cause a reduction in gross log scale; they must show no more than 4 inches of actual sweep, no more than 4 degrees of lean, and no more than four surface indicators of defects that would limit clear cuttings. With some training and practice most workers can readily apply these relatively simple specifications, and the forest manager will not have to use his time to select the trees or to give constant supervision.

Say that the forest manager decides to invest in trees with a 50 percent or higher probability of producing grade-1 logs at maturity. He merely changes his instructions to include trees with five and six surface defect indicators (table 2). In doing this, he is selecting some grade-2 growing-stock trees along with his grade-1 trees. Thus, table 2 provides the manager with flexibility in selecting the quality of young trees to suit his goals; and at the same time he can maintain the desired stand density.

Say that our forest manager has a surplus of grade-2 trees,

and he wants to prune those that can be changed to grade-1 trees with a minimum investment. Which trees shall he prune? Obviously, he should prune only those trees by which he can substantially increase the probability of their yielding a grade-1 sawlog upon reaching 16 inches d.b.h. Probability figures from table 2 show that the greatest improvement in log quality occurs when the number of log-defect surface indicators is reduced from eight to four. In this range the elimination of a single log defect increases by 10 to 15 percent the probability that the trees will yield grade-1 butt logs.

Thus, pruning efforts should be limited to growing-stock trees that qualify for grade 1 except that they have five to eight branches. New branches may form after the first pruning. But, if only one less branch forms than those originally present, a substantial gain is made in the probability of growing grade-1 logs. With an expectation of increasing the probability of grade-1 log yield by 10 to 15 percent by eliminating a single log defect, the forest manager can justify repeated pruning of selected trees. Pruning of a tree that has only a grade-2 butt log potential should be done only rarely.

A forest manager could also rate a group of young hardwood stands according to their expected yield of grade 1, grade 2, and grade 3 logs when the trees reach 16 inches d.b.h.

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Growth of APPALACHIAN HARDWOODS as affected by site and residual stand density

by George R. Trimble, Jr.

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U.S. FOREST SERVICE RESEARCH PAPER NE-98
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

Growth of
APPALACHIAN
HARDWOODS
as affected by site and
residual stand density

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INTRODUCTION

THE MANIPULATION of stand density is one of the primary tools that foresters use to regulate tree growth. By reducing stand density, it is possible to stimulate the growth of the residual trees and concentrate the volume on a smaller number of more valuable trees. Total stand volume production is not greatly affected by this procedure as long as density is not reduced below the point where the trees fully occupy the site.

Proper regulation of growth requires a thorough knowledge of the effect of varying densities on stand behavior. How low can density be dropped without reducing total volume production? How much is individual tree growth stimulated by reduced density? What effect does site have on the choice of stand density?

To answer these questions for Appalachian hardwoods, a study was made to determine the effect of varying residual basal area on subsequent stand growth. An excellent site and a fair one were selected for the study.

THE STUDY

Description of Area

The study was conducted in undisturbed hardwood stands on the Fernow Experimental Forest near Parsons, West Virginia. Though most of the trees were 48-year-old second-growth, there were a number of scattered old-growth stems that were left from the previous logging in the virgin timber.

Species composition varied between the sites studied. On the excellent site, yellow-poplar (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), northern red oak (*Quercus rubra* L.), and sugar maple (*Acer saccharum* Marsh.) predominated. Other species in mixture were white ash (*Fraxinus americana* L.), beech (*Fagus grandifolia* Ehrh.), basswood (*Tilia americana* L.), cucumbertree (*Magnolia acuminata* L.), black locust (*Robinia pseudoacacia* L.), hickory (*Carya sp.* Nutt.), and red maple (*Acer rubrum* L.),

The fair site was characterized by chestnut oak (*Quercus prinus* L.), red oak, white oak (*Quercus alba* L.), scarlet oak (*Quercus coccinea* Muenchh.), red maple, black locust, black gum (*Nyssa sylvatica* Marsh.), and sassafras (*Sassafras albidum* (Nutt.) Nees).

These differences in species composition between the two sites are typical of those between other similar sites throughout the Appalachian hardwood region. The better sites characteristically have a higher proportion of the more valuable and faster growing species. Within each site, species composition was relatively uniform so that differences in the proportion of fast-growing species on a plot should have had little effect on the study results. The one possible exception to this is that the high-density plots on the excellent site had a lower proportion of the fast-growing

red oak and yellow-poplar than did the other four plots on the same site.

Another characteristic difference between the two sites was that trees of equal diameter had greater merchantable heights on the better site (table 6, appendix). Thus a given increase in diameter resulted in a proportionately larger volume increase on the better site.

While the second-growth was relatively even-aged, it contained a wide range in diameter classes. This is typical of mixed stands of Appalachian hardwoods (*Gibbs 1963*).

Located at an elevation of nearly 3,000 feet, this area is subjected to a rather cool climate. The frost-free growing season is 130 to 140 days and the average temperature is 48° Fahrenheit. Average annual rainfall is about 60 inches and is fairly well distributed throughout the year. Snowfall is heavy in the winter. The soils are medium-textured and are well-drained.

Methods

In 1954, twelve 2½-acre plots were laid out; six of them were located on an excellent site — about site index 85 for oak — and six on a fair site — about site index 63 for oak — (*Schnur 1937; Trimble and Weitzman 1956*). The areas were well stocked before cutting (table 1).

The plots were marked for cutting to specified basal areas to obtain a comparison of growth rates by sites and stocking levels. Three residual basal areas in trees over 5.0 inches d.b.h. were chosen for each site, and replicated plots were marked accordingly. For the better site, residual basal areas were 100, 80, and 60 square feet. For the poorer site, the levels were 75, 60, and 45 square feet. These levels were based on local experience as well as literature review, and were chosen to represent a reasonable range of residual stocking. Cutting resulted in only slight variations from the specified levels (table 1).

Basal area in trees over 5 inches d.b.h. is used as the expression of stand density throughout this paper. Other expressions, such as basal area in trees over 11 inches d.b.h., were also tested, but results were similar in all cases.

Table 1.—The initial stand

Density	D.b.h.	Basal area[1]	Cubic volume	Board volume[2]
	Inches	*Square feet per acre*	*Cubic feet per acre*	*Board feet per acre*
		BEFORE CUTTING		
Excellent site:				
High	11.3	134	3,510	14,900
Medium	11.4	133	3,480	14,900
Low	11.6	130	3,420	15,100
Fair site:				
High	10.3	93	2,070	8,500
Medium	9.0	92	1,900	5,400
Low	9.0	90	1,910	5,600
		AFTER CUTTING		
Excellent site:				
High	10.8	100	2,570	10,100
Medium	10.6	80	2,050	7,800
Low	10.0	59	1,490	5,200
Fair site:				
High	9.9	72	1,560	5,800
Medium	10.0	59	1,260	4,100
Low	9.6	46	970	3,200

[1] See table 7 for breakdown of residual basal area by size classes.
[2] Volume to an 8-inch top inside bark as determined by the International ¼-inch kerf rule.

To leave a distribution of size classes typical of local unmanaged second-growth stands, cutting was done throughout the range of tree diameters above 9.0 inches d.b.h. In essence, the old residuals were removed and the plots were thinned at different intensities throughout the stand structure by this operation. To guide the distribution of stem sizes to be left, a "Q" of 1.6 was chosen since it was found to be typical of unmanaged hardwood stands in the area. "Q" is the quotient of number of trees in a 2-inch d.b.h. class divided by the number in the next larger class (*Meyer 1952*).

One-hundred-percent inventories of trees over 5.0 inches d.b.h. were made at 2-year intervals throughout the 10-year study period. A 10-percent systematic sample was taken of stems 1 to 5 inches d.b.h. on 1/100-acre plots.

After 10 years, a random sample of butt log grades was taken — using standard Forest Service factory-log grades (*Ostrander 1965*) — on the sawlog trees. In addition, epicormic branching by 8-foot bole sections was recorded on every fifth tree over 5.0 inches d.b.h. These observations provided a basis for judging the effect of treatment on log quality.

Four types of growth were studied: (1) cubic volume, (2) board-foot volume, (3) basal area, and (4) diameter. Growth calculations were based on the first 10 years after cutting. Cubic volume, based on a local volume table, was computed to a 4-inch top inside bark for all trees over 5.0 inches d.b.h. Board-foot volume, based on a local volume table, was computed to an 8-inch top inside bark (or to where the stem split up into crown) for all trees over 11.0 inches d.b.h.

Statistical testing of growth differences due to site or residual stand density was done through regression analysis.

RESULTS

Cubic-Volume Growth

Annual net cubic-volume growth of the merchantable stand did not appear to be related to residual stand density (table 2). However, when this growth was broken down by stand segments (growth on trees 5 to 11 inches d.b.h. and on trees 11 inches

Table 2.—Annual cubic-volume growth, in cubic feet per acre per year

Density	Accretion	Net growth	Ingrowth	Mortality
		EXCELLENT SITE		
High	90.6	93.2	8.0	5.4
Medium	91.6	96.6	10.0	5.0
Low	83.7	91.7	12.5	4.5
All densities	88.6	93.8	10.2	5.0
		FAIR SITE		
High	51.2	59.8	9.3	.7
Medium	56.0	66.5	19.2	8.8
Low	52.9	70.2	19.0	1.7
All densities	53.3	65.5	15.9	3.7

d.b.h. and larger), there were significant relationships with density, as follows:

	Trees 5 inches to 11 inches d.b.h.	*Trees more than 11 inches d.b.h.*
Excellent site:		
High density	—15	109
Medium density	—4	100
Low density	5	87
Fair site:		
High density	10	50
Medium density	12	55
Low density	19	51

Cubic-volume growth of the smaller trees (5 to 11 inches d.b.h.) increased at the lower densities. These differences were significant at the 5-percent level on the excellent site and at the 10-percent level on the fair site. In contrast, cubic-volume growth of the larger trees (11 inches and larger d.b.h.) decreased significantly (5 percent level) at the lower densities on the excellent site, although there was no such relationship on the fair site.

Ingrowth across the 5-inch threshold was generally greatest at the lower densities. However, differences large enough to attain statistical significance (5-percent level) occurred only on the fair site between the high density and the other two densities. There were no significant differences in mortality.

Cubic-foot growth percent (net growth expressed as a percentage of the initial volume) increased significantly (5-percent level) with decreasing density on both sites. Growth percent on the excellent site averaged 3.8 percent on the high-density plots as compared with 6.5 percent on the low-density plots. Corresponding figures for the fair site were 3.9 and 7.4 percent respectively.

Cubic-foot volume growth was significantly (5-percent level) higher on the better site. For all trees 5 inches d.b.h. and larger, net growth was 1.4 times larger and accretion was 1.7 times larger on the excellent site than it was on the fair site.

Board-Foot Volume Growth

Annual net board-foot volume growth of the merchantable stand was significantly (10-percent level) related to density on

Table 3.—Annual board-foot volume growth, in board feet per acre per year

Density	Accretion	Net growth	Ingrowth	Mortality
		EXCELLENT SITE		
High	462	681	219	0
Medium	450	656	206	0
Low	360	544	184	0
All densities	424	627	203	0
		FAIR SITE		
High	188	295	107	0
Medium	136	310	188	14
Low	142	293	151	0
All densities	156	299	149	5

the excellent site (table 3). The low-density treatment had significantly less board-foot growth than the other two densities. No relationship was found between density and board-foot growth on the fair site.

Board-foot growth percentage increased significantly (5-percent level) with decreasing density on both sites. Growth percent on the excellent site averaged 6.8 percent on the high-density plots and 10.2 percent on the low-density plots. Corresponding figures for the fair site were 5.6 and 9.0 percent respectively.

Board-foot volume growth was significantly higher (5-percent level) on the better site. Net growth was 2.1 times larger and accretion was 2.7 times larger on the excellent site than it was on the fair site.

Basal-Area Growth

Net basal-area growth in trees over 5 inches d.b.h. showed no relationship to stand density. However, when this growth was broken down by stand segments, there were significant relationships (table 4). Basal-area growth in small trees (5 to 11 inches d.b.h.) increased with the lower stand densities; these differences were significant at the 5-percent level on both sites. In contrast, basal-area growth of the larger trees (11 inches and larger d.b.h.) decreased significantly (5-percent level) at the

Table 4.—Annual net basal-area growth, in square feet per acre per year

Density	Tree size, d.b.h.		Total
	5 to 11 inches	More than 11 inches	
	EXCELLENT SITE		
High	—0.6	3.8	3.1
Medium	—.2	3.4	3.3
Low	.3	3.0	3.3
All densities	—.2	3.4	3.2
	FAIR SITE		
High	.5	1.9	2.4
Medium	.6	2.2	2.9
Low	1.0	2.0	3.1
All densities	.7	2.0	2.7

lower densities on the excellent site. There was no such relationship with the larger trees on the fair site.

Basal-area growth was higher on the better site for total trees and for the larger trees. Basal-area growth of small trees was higher on the fair site because of the lighter overstory.

Diameter Growth

Diameter growth rates were computed separately for each of the three most numerous species on each site. On the excellent site, red oak grew faster than yellow-poplar, which in turn grew faster than black cherry. These differences were significant at the 5-percent level (table 5). Red oak also responded more to differences in release than did yellow-poplar. Black cherry apparently did not respond to release at all. On the fair site, there were no significant differences between the three most numerous species, although the trend of decreasing growth from red oak to chestnut oak to white oak was in line with a previous report (*Trimble 1960*). Early growth of these species on both sites in the undisturbed stands had apparently been similar since there were no significant differences in initial diameters.

Diameter growth of the residual trees was significantly (5-

Table 5.—Ten-year diameter growth, in inches, of three most numerous species on each site — sawtimber trees only, more than 11 inches d.b.h.

Density	Yellow-poplar	Black cherry	Red oak	Chestnut oak	White oak	All species[1]	All species[1] more than 5 inches d.b.h.
			EXCELLENT SITE				
High	2.4	1.7	2.9	—	—	2.2	1.4
Medium	2.5	2.1	3.3	—	—	2.6	1.6
Low	2.7	1.9	3.9	—	—	2.8	1.8
			FAIR SITE				
High	—	—	1.7	1.6	1.6	1.8	1.2
Medium	—	—	2.0	1.8	1.9	1.8	1.5
Low	—	—	2.5	2.2	1.5	2.4	1.9

[1] Includes growth of all trees present, regardless of species.

percent level) greater at the lower stand densities on both sites (table 5).

Because of greater ingrowth at the lower densities, average stand diameter was not greatly affected by stand density. Average stand diameters on the excellent site of 10.0, 9.9, and 9.4 inches for the high-, medium-, and low-density plots respectively had increased to only 11.0, 10.8, and 10.2 inches after 10 years. Similar figures for the fair site were 9.0, 9.0, and 8.9 inches immediately after cutting and 9.6, 9.2, and 9.0 inches after 10 years.

Diameter growth was significantly higher on the better site. The diameter growth rate of red oak, the one species common to both sites, was 1.6 times larger on the excellent site than it was on the fair site.

Log-Quality Changes

Butt-log grade comparisons made at the end of the study showed no important quality differences attributable to treatments. Epicormic branching comparisons made by species and crown-class likewise revealed no important differences due to density for red oak and yellow-poplar on the excellent site. It appeared that epicormic branching increased at the lower stand

densities on black cherry — but only on the stem above 32 feet; i.e., above the first two logs.

On the fair site, comparisons of epicormic branching on the first two logs revealed no treatment effects for white oak, red oak, and chestnut oak (the only species sampled in sufficient numbers for testing). There were not enough samples with more than two logs to make valid comparisons above 32 feet on the fair site.

It should be recognized that epicormic branching differences might possibly have shown up a few years after cutting and the branches might have died and fallen off because of increasing stand density before the 10-year observations.

DISCUSSION

The results of these experiments may be summarized briefly:

- Low stand densities produced the greatest growth of individual trees.
- Low stand densities favored the growth of the smaller trees in the stand; i.e., trees 5 to 11 inches d.b.h. and trees growing across the threshold diameter.
- Low stand densities reduced the total growth of the larger trees in the stand on the excellent site but had no effect on them on the fair site.
- Stand density had no effect upon total growth of the entire stand above 5 inches d.b.h.
- Stand density had no important effects on log quality.
- The excellent site produced considerably more growth than the fair site.

A landowner or manager interested in bulk products — where size and clear wood are not important considerations — could obtain about equal volume production from any of the densities tested. To maximize his return on investment (growth percentages on residual volume) he should utilize the lower densities: 60 square-foot residual basal area on the excellent site or 45

square-foot residual basal area on the fair site. If this production were to be maintained indefinitely through partial cuttings, it would be important to maintain about 15 square feet of basal area in the 1- to 5-inch d.b.h. class to provide for ingrowth.

However, it should be emphasized that the better sites would normally be devoted to growing veneer and sawtimber, and small products would be harvested only as byproducts.

A landowner or manager interested in sawtimber and veneer production on a fair site could also obtain about equal volume production and maximize his return on investment by cutting to 45 square feet of basal area. There would be little or no reduction in quality due to epicormic branching as long as he maintained 15 to 20 square feet of basal area in stems in the 1- to 5-inch d.b.h. class to shade the first two logs of larger stems.

However, on the better sites, the decision is more difficult. Residual stand density can be reduced to about 80 square feet of basal area without reducing board-foot growth and with no appreciable reduction in quality due to epicormic branching. Reducing residual basal area further would have several opposing effects in stands such as these: it would reduce total sawtimber production but it would increase individual tree growth rate and size and reduce the investment in growing stock. In cases where stands would be managed indefinitely by partial cuttings, it is recommended that residual density be held at 80 square feet of basal area per acre. In cases where even-aged management would be applied, it might be desirable to reduce density further, depending upon the desired rotation ages, value differentials attributable to larger size, etc.

■

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APPENDIX

Table 6.—Merchantable heights of sawtimber size trees, in feet

D.b.h. (inches)	Excellent site	Fair site
14	41	29
16	47	33
18	44	34
20	45	36
22	53	40

Table 7.—Residual basal area, by size classes, in square feet per acre

Density	Size class, d.b.h.			
	1 to 5 inches	5 to 11 inches	More than 11 inches	Total, more than 5 inches
		EXCELLENT SITE		
High	13.8	35.5	64.3	99.0
Medium	15.9	31.2	48.8	80.0
Low	13.7	26.2	33.2	59.4
		FAIR SITE		
High	17.6	30.4	41.9	72.3
Medium	16.1	29.4	29.4	58.8
Low	18.2	22.7	23.2	45.9

Early
REPRODUCTION
after seed-tree harvest cuttings in Appalachian hardwoods

by George W. Wendel
and George R. Trimble, Jr.

U.S. FOREST SERVICE RESEARCH PAPER NE-99
1968

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Early REPRODUCTION after seed-tree harvest cuttings in Appalachian hardwoods

INFORMATION NEEDED

EVEN-AGED MANAGEMENT is gaining wide-acceptance in eastern hardwoods because it offers the promise of increased timber returns. Much of this increase results from the faster growth and higher value of the shade-intolerant or intermediate species that are perpetuated under this system. To obtain maximum benefit from even-aged management it is important that regeneration of the desired species be obtained promptly after the final harvest cutting. Information about the nature and timing of regeneration obtained from cuttings under various conditions is needed to facilitate the prescription of cutting methods or treatments that will accomplish this objective.

This report describes the quantity, origin, and species composition of the reproduction that was present 3 years after seed-tree harvest cuttings in Appalachian hardwood stands on the U. S. Forest Service's Fernow Experimental Forest near Parsons, West Virginia. This reproduction study was part of a much larger long-term study of three intensities of even-aged management on three site-quality classes.

STUDY AREAS AND METHODS

The study was carried out on nine compartments: three each on areas of site index 60, 70, and 80 (based on 10-foot oak site-index classes). These indexes characterize sites that are referred to respectively as fair, good, and excellent. The first compartment was established and cut in 1959 and the last one 3 years later. Eventually the areas will be subjected to treatment programs of different intensities, but at this date the only effective independent variables are site quality and the associated differences in species composition of the harvested stands and seed trees.

The same harvest-cutting procedure was used on all study areas. All trees over 5 inches d.b.h., except designated seed trees, were logged. Three growing seasons later, the seed trees were removed.

The original stands (fig. 1) were well stocked and had not been disturbed by cutting or fire for at least 35 years. All of them contained considerable sawtimber volume. The predominant or characteristic species were hickories, sugar maple, red oak, white ash, and black cherry on the excellent sities; yellow-poplar, red oak, hickories, chestnut oak, and white oak on the good sites; and chestnut oak, red oak, black gum, and white oak on the fair sites.

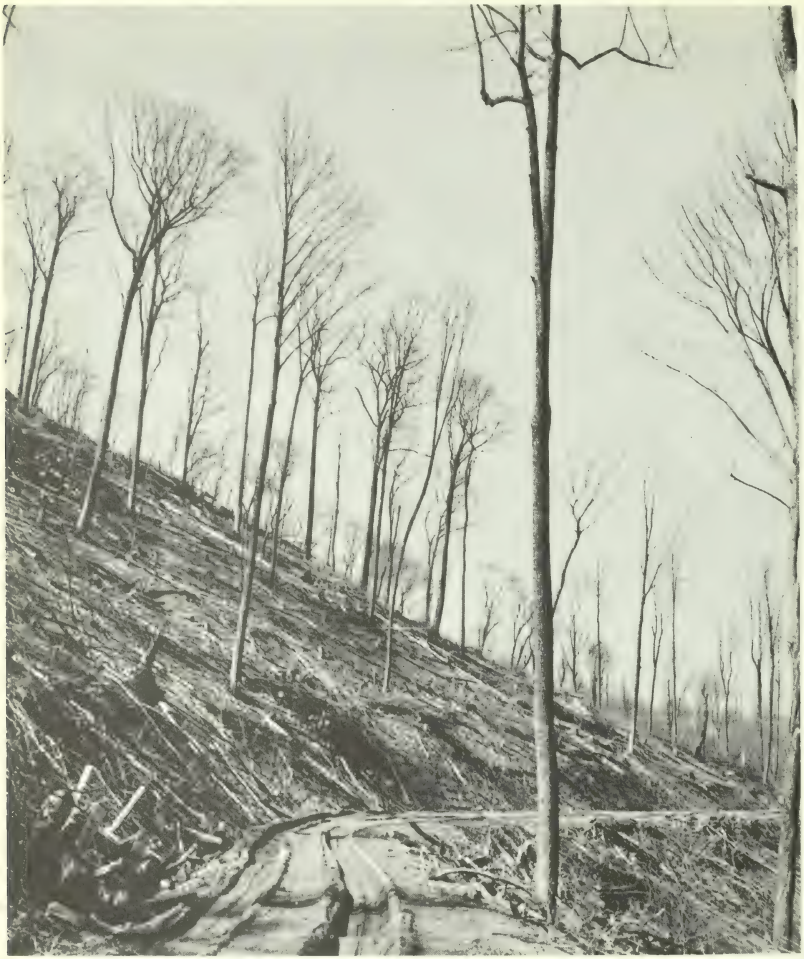
The number of seed trees left (fig. 2) after the initial logging depended on the site. On the lower site-quality areas we felt that more seed trees were needed to obtain adequate distribution of seed because of the greater proportions of the heavy-seeded oaks.

Figure 1.—Typical excellent-site stand before cutting.

By site-index classes we left the following numbers of trees per acre: site index 60 — 30 trees, site index 70 — 20 trees, and site index 80 — 10 trees.

A large proportion of the sawtimber trees on all the excellent sites and on one fair site and one good site were old-growth trees 90 to 100 years old (fig. 2). The sawtimber trees on the other sites were chiefly second growth, 55 to 60 years old, with a few old-growth residuals (fig. 3).

Figure 2.—Seed-tree stand left on one of the excellent sites.



To document closely the development of the new stands, we measured the reproduction before and after the harvest cuttings, and before and after seed-tree removal. Tallies were made by species, size class, and stem origin. Two size classes of reproduction were recognized: *small* (1 foot high to 1 inch d.b.h.) and *large* (1 inch to 5 inches d.b.h.). Small reproduction was sampled on milacre plots and large reproduction on 1/100-acre plots. Reproduction was tallied as seedlings or stump sprouts. The

Figure 3.—Typical fair-site stand before cutting.

seedling category included seedling sprouts, defined as stems arising from stumps less than 2 inches in diameter at ground line.

In the original stands the reproduction inventory in each compartment was done by sampling 1 percent of the area for the small stems and 10 percent of the area for the large stems. All reproduction tallies after the harvest cutting were made at 45 permanent sampling points in a 5-acre area in the center of each compartment.

RESULTS

Reproduction at the End of Three Growing Seasons

Abundance. — Small reproduction for all compartments ranged from 6,382 to 18,399 stems per acre and averaged 12,373 (table 1 and figs. 4 and 5). No significant difference in the total number of stems was detected among site classes at the 5-percent level. These results are in accord with those reported by Trimble and Hart (*1961*) in West Virginia and Roach (*1963*) in Ohio.

Table 1.—Small reproduction[1] at the end of three growing seasons

Compartment No.	Total stems per acre	Sprout stems per acre[2]	Sprouts	Five most numerous species, and number of stems per acre					Other species per acre	Millacres stocked with commercial species
				First	Second	Third	Fourth	Fifth		
	No.	*No.*	*Percent*						*No.*	*Percent*
						EXCELLENT SITE				
32	8,082	800	10	Sweet birch 3,330	Sugar maple 2,398	White ash 555	Yellow-poplar 466	Black cherry 222	1,111	91
33	18,399	1,528	8	Sweet birch 7,104	Sugar maple 5,305	White ash 2,620	Yellow-poplar 977	Black cherry 575	1,818	91
43	13,533	5,711	42[3]	Sugar maple 4,024	Black cherry 2,934	Yellow-poplar 2,422	White ash 1,022	Hickory 711	2,420	96
						GOOD SITE				
36	12,012	4,246	38	Sassafras 3,300	Yellow-poplar 2,002	Sugar maple 1,672	Black locust 946	Black gum 594	3,498	96
37	6,382	3,361	53	Sugar maple 1,749	Yellow-poplar 841	Red oak 840	White ash 750	Sassafras 431	1,771	91
39	12,154	2,377	20	Sugar maple 4,200	Yellow-poplar 2,800	Black cherry 1,444	Sweet birch 1,223	White ash 1,022	1,465	100
						FAIR SITE				
34	15,142	5,818	38	Sassafras 7,593	Chestnut oak 3,042	Red maple 2,064	Red oak 844	Sweet birch 710	889	93
35	13,185	4,640	35	Sassafras 4,928	Sweet birch 3,730	Red maple 1,798	Chestnut oak 533	Black locust 444	1,752	98
38	12,484	6,530	52	Sassafras 4,111	Chestnut oak 2,400	Sourwood 2,266	Red maple 1,598	Red oak 889	1,220	98

[1] Stems 1 foot high to 1 inch. d.b.h.
[2] Sprouts include root suckers of American beech and black locust.
[3] For this compartment only, sprout tallies included seedling sprouts.

Figure 4.—Small reproduction on an excellent site 3 years after cutting.

Trimble and Hart reported over 10,000 stems of small reproduction per acre 5 years after clearcutting Appalachian hardwood stands; Roach reported 4,000 to 8,000 stems per acre after clearcutting upland hardwood stands in Ohio.

Of the total stems of small reproduction, 10 to 53 percent were of sprout origin (table 1). However, these figures tend to inflate the importance of sprouts because many sprouts may arise from a single stump. Our measurements also showed a higher percentage of sprouts on the good and fair sites than on the excellent sites. The range in percentage of sprout-origin stems

Figure 5.—Small reproduction on a good site 3 years after cutting.

concurs with the results reported earlier by Trimble and Hart (*1961*).

On the average, sugar maple was the most numerous species on the excellent and good sites, although it did not rank first in every instance. Sassafras was most numerous on the fair sites. Sweet birch ranked high on two of the excellent sites and on one fair site; yellow-poplar ranked second on all three good sites. Rankings of the top five species on each site are shown in table 1.

Most of the large reproduction stems were carryovers of advance reproduction that had survived the first harvest cutting; a

few were fast-growing stump sprouts. The average number ranged from 107 per acre on the excellent sites to 208 on the fair sites. Being generally poor in form and few in number, most of these stems are undesirable elements in the new stand.

Distribution. — After 3 years, 91 to 100 percent of the milacres on all sites were stocked with one or more seedling or sprout stems of small reproduction (table 1). A large proportion of the milacres on the excellent and good sites were stocked with the desirable intolerant species — yellow-poplar, black cherry, and white ash — and with sugar maple (table 2). On the fair sites a majority of the milacres were stocked with sassafras; but chestnut oak, red oak, and other commercial species also were fairly well distributed. The ten top-ranking species in terms of stocked milacres are shown for each site in table 2.

The role of advance reproduction. — The quantity, species composition, and distribution of small reproduction on the ground before cutting differed markedly from that present 3 years later.

Advance small reproduction ranged from 1,200 to 4,500 stems per acre; 3 years after cutting the range was 6,382 to 18,399 stems per acre. This increase occurred despite severe damage to or destruction of 53 to 72 percent of the advance-growth stems during the initial harvest cuttings. Of course many of the stems damaged in logging undoubtedly resprouted from the base and formed part of the 3-year tally. Merz and Boyce (*1956*) have shown that such resprouting occurs with the oaks. Sterrett (*1915*) reported that white ash seedlings will resprout for 5 to 20 years under oak canopies and for 10 to 15 years under northern hardwood and yellow-poplar canopies. Resprouting of sugar maple and young black cherry seedlings has been observed on the Fernow Experimental Forest.

Sugar maple was the most abundant species in the small advance reproduction on the excellent and good sites, and sassafras was most abundant on the fair sites. Both species still retained these positions in the small reproduction 3 years after logging, but marked changes or regroupings occurred among the four next most numerous species (table 3). The changes were more pronounced on the excellent sites than on the good and fair sites.

Table 2.—Percentage of milacres stocked with commercial species of small reproduction at the end of 3 years (10 species with best stocking, per compartment)

Compartment No.	1	2	3	4	5	6	7	8	9	10
	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking	Species and % stocking
					EXCELLENT SITE					
32	Sugar maple 64	Sweet birch 44	Yellow-poplar 27	White ash 24	Black cherry 16	Hickory 16	Black locust 13	Elm 9	Red oak 7	Cucumber 7
33	Sweet birch 69	Sugar maple 67	Yellow-poplar 51	White ash 33	Elm 24	Butternut 20	Basswood 13	Red oak 11	Black cherry 7	Black locust 4
43	Yellow-poplar 64	Sugar maple 58	Black cherry 49	White ash 29	Hickory 27	Black locust 24	Sweet birch 9	Red oak 9	Elm 9	Red maple 4
					GOOD SITE					
36	Sassafras 58	Sugar maple 49	Yellow-poplar 33	Red oak 24	Hickory 16	Red maple 16	Chestnut oak 13	White ash 9	Sourwood 7	Black cherry 7
37	Sugar maple 44	White ash 40	Yellow-poplar 22	Sassafras 16	Red oak 11	Sweet birch 11	Chestnut oak 7	Hickory 7	Black gum 4	Elm 2
39	Yellow-poplar 67	Sugar maple 49	Black cherry 31	Sweet birch 31	White ash 27	Black locust 13	Hickory 11	Red maple 7	Red oak 4	Sassafras 4
					FAIR SITE					
34	Sassafras 62	Chestnut oak 20	Sweet birch 18	Red oak 18	Red maple 18	Sourwood 13	Yellow-poplar 11	Sugar maple 2	Black gum 2	— —
35	Sassafras 58	Sweet birch 40	Red maple 29	Red oak 20	Chestnut oak 13	Black gum 9	Black locust 7	Magnolia 4	Black locust 4	Sourwood 4
38	Sassafras 71	Red oak 31	Sourwood 27	Black gum 24	Chestnut oak 22	Cucumber 4	Sweet birch 4	Aspen 2	Scarlet oak 2	Red maple 2

Table 3.—Ranking of five most numerous species in the small advance reproduction and in the small reproduction 3 years after the cutting, (average by site).

(1 foot high to 1 inch. d.b.h.)

Site quality	Rank	Advance reproduction	3 years after initial reproduction cut
Excellent	1	Sugar maple	Sugar maple
	2	Hophornbeam	Sweet birch
	3	Beech	White ash
	4	Basswood	Yellow-poplar
	5	Fraser magnolia	Black cherry
Good	1	Sugar maple	Sugar maple
	2	White ash	Yellow-poplar
	3	Red maple	Sassafras
	4	Red oak	White ash
	5	Black oak	Red oak
Fair	1	Sassafras	Sassafras
	2	Chestnut oak	Red maple
	3	Red maple	Chestnut oak
	4	Sugar maple	Sweet birch
	5	Black gum	Red oak

Before cutting, milacre stocking of the advance small reproduction for the excellent, good, and fair sites was 39, 75, and 85 percent respectively. After the first harvest cutting the respective milacre stockings averaged 27, 37, and 33 percent; 3 years later the figures were 93, 96, and 96 percent; and after seed-tree removal they were 87, 88, and 93 percent. These last figures undoubtedly were soon increased by the resprouting of damaged stems.

As mentioned previously, the larger stems of advanced reproduction are generally an undesirable component. They are usually made up of the less desirable species; they frequently have poor form; and their stocking is seldom dense enough for good quality growth (fig. 6). Many of them develop excessively large crowns and interfere with the development of smaller and more desirable stems. Although there is little published information to show that removal of these trees is economically justified,

Figure 6.—Large advance reproduction on the fair site after seed-tree removal.

most foresters who have studied their development recommend that they be eliminated when harvest cuts are made, or shortly after.

Other Considerations

Logging slash and herbaceous ground cover. — Both logging slash and heavy herbaceous ground cover can be detrimental to the establishment of desirable reproduction. In this study, detailed note was made of logging slash and casual observation was made of herbaceous ground cover.

After the first reproduction cutting, logging slash covered an average of 21 percent of the ground surface. Since pulpwood was harvested from this cutting as well as sawlogs, much of the

heavier sawlog slash was utilized. After the seed-tree cutting — when no pulpwood was harvested except on compartment 38 — the average coverage by logging slash increased to 26 percent.

Our observations indicate that reproduction is reduced or at least delayed by the larger and denser slash piles until they have broken down, which occurs in 3 to 5 years. But we do not know to what extent this hinders the ultimate stocking and development of reproduction.

Only on two of the excellent-site compartments was there a heavy cover of herbaceous vegetation before the harvest cutting. As of 1966, this cover has persisted 5 years (fig. 7). Wood nettle (*Laportea canadensis*), pale snapweed (*Impatiens pallida*), black snakeroot (*Cimicifuga racemosa*), wild hydrangea (*Hydrangea*

Figure 7.—Heavy herbaceous growth on the excellent site 3 years after cutting.

arborescens), blackberry (*Rubus* sp.), and other high-site species blanket the area. Although the effect of this competition does not show up in the reproduction counts, the seedlings are shorter on these compartments than on the other high-site compartment. After 5 years, the new tree stand was just emerging from this layer. Only time will tell whether the reduction in early height growth will later be made up.

Seed trees. — Because of their sudden isolation from the protection afforded by a closed stand, seed trees retained after harvest cutting are subject to log-quality degrade by epicormic branching, and to losses from windthrow.

Epicormic branching. — Some epicormic branching was noted on several species left as seed trees on the better sites. These trees were dominants and codominants with good crowns — types of trees that are least susceptible to bole sprouting. During the 3 years the seed trees were standing, some epicormic branches developed on the first two logs of black cherry and basswood; there was no increase in epicormic branching on yellow-poplar and white ash. This is in line with results reported by Smith (*1966*).

Windthrow. — Some blowdown of seed trees occurred on the excellent-site compartments where only 10 seed trees per acre were left. Of a total of 470 seed trees on these three compartments, about 20 of them — ranging from 14 to 32 inches d.b.h. — were lost. High winds after heavy rains in February 1962 probably caused the blowdown. About equal numbers of basswood, red oak, white ash, and black cherry—the predominant seed trees species—were uprooted. Most of the damage occurred on a flat exposed ridge. No seed trees on the good and fair site compartments were blown down.

DISCUSSION

Our goal for regeneration in even-aged management is to obtain adequate stocking to desirable species during and shortly after the harvest cutting, or cuttings in the case of seed-tree and shelterwood systems. Our study demonstrated that this objective

can be met, and it brought to light a number of pertinent facts concerning the process.

The important considerations are the quantity, distribution, and species composition of the reproduction that is present a short time after cutting. In our compartments the reproduction 3 years after harvest was satisfactory in all respects. There were more than enough well-distributed seedling and seedling-sprout stems to produce new stands of well-formed trees of desirable species if timely intermediate cuttings, such as weedings and thinnings, are carried out.

Species composition varied with site quality. Sugar maple was the predominant species on the excellent and good sites both before and 3 years after cutting, but such highly desirable intolerant species as yellow-poplar, black cherry, basswood, and white ash were abundant enough after cutting to form an important part of the new stands. Sassafras, a short-lived species, was prominent in the reproduction on the fair sites — both before and after cutting. However, the oaks and red maple were sufficiently numerous and well-distributed to stock the new stands if favored in intermediate cuttings.

Considering the abundance of reproduction stems, the damage caused by seed-tree removal was not important and therefore can generally be ignored.

Recent information about several species, notably yellow-poplar and white ash, has revealed that seeds stored in the duff can play a major role in regenerating new stands (*Clark 1962, Leak 1963, Sander 1966*). Black cherry probably falls in this same category; however, there is little published information about the relative importance of black cherry seed that has been stored in the duff. Advanced reproduction is also very important in the regeneration of certain species. Oaks that survive in the regeneration have been found to consist primarily of stump sprouts and new sprouts from advanced reproduction present under the old stand (*Sander 1966*). Thus there would seem to be little need to leave seed trees in situations where advanced reproduction is present or where seed of desired species can be expected in the duff.

Certain classes of vegetation present on the study areas 3 years after logging are potentially detrimental to the new stands. These include the scattered stems of large advance reproduction, which can be cheaply eliminated by basal spraying or injecting with herbicides. The other competitors, rhododendron and grapevines, are most prevalent on the better sites, and controlling them is costly. More work is needed to develop economically feasible control methods. Although briars and herbaceous plants may depress tree-seedling growth somewhat during the early years, expenditures for control of these plants probably would not ordinarily be justified.

Logging slash has not materially affected the establishment of new reproduction on the study areas. Under the heavier piles of brush, which in places completely covered areas of several square feet, reproduction has not come in. However, these spots occupy only a small part of the total area in any of the compartments, and they are scattered.

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DESIGN & ANALYSIS

for multiple-use studies of deer browse & timber production

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Stephen A. Liscinsky

U. S. FOREST SERVICE RESEARCH PAPER NE-100
1968
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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DESIGN & ANALYSIS

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PURPOSE

A PRIMARY purpose of resource management on forested state game lands is usually to preserve or enhance the recreational value of the lands for hunting by producing an adequate and continuing supply of food and cover for wildlife. This objective is ordinarily obtained through sustained-yield management of the timber. Under this type of multiple-use management *(Society of American Foresters 1958)*, manipulation of the stand structure for wildlife values is planned, whenever possible, to provide for thinning or harvesting operations that are conducive to good timber yields. When this is done successfully, the combined values of hunting and timber production provided by a given piece of land should exceed the value that could be derived from a single use of the same land.

The purpose of this paper is to discuss the design and analysis of experiments for comparing the production of dormant woody deer browse under various intensities of cutting. The discussions are based on first-year results of an experiment that was begun in 1961 on State game land in northeastern Pennsylvania by the Pennsylvania Game Commission and the U. S. Forest Service.

This cooperative study was designed primarily to compare the effects of a wide range of cutting intensities in pole-sized hardwood stands on annual and total dormant browse production during the first 5-year period after treatment. Also, as a secondary objective, the growth and quality of residual timber and the abundance of sprout and seedling reproduction within each treatment will be compared 10 years after treatment and again 20 years after treatment.

The design of the experiment, together with suggestions for improving similar studies in the future, may be of value to others who deal with multiple-use research involving deer and timber. Also, the statistical procedures used to analyze first-year results may prove useful *(Morris et al. 1959).*

Because no timber growth or quality data are available yet, this paper covers only the browse aspects of the study and preliminary results on deer and rabbit use.

STUDY DESIGN

The Area

The study was established on 65 acres of a 50-year-old second-growth northern hardwood stand of primarily sprout origin. Site, aspect, soil, and cover type were fairly uniform throughout the 65 acres. Basal area of all trees 4.6 inches d.b.h. and larger was 90 $\pm$ 4 square feet (1 standard error) per acre as determined with a basal-area angle gage at 30 random sampling points. Basal area of trees below 4.6 inches d.b.h. was approximately 20 square feet per acre throughout the study area.

Treatments

Five cutting treatments—reserving 0 (clearcut), 15, 30, 45, and 60 square feet per acre in the residual stand—and an uncut control (fig. 1) were established in two randomized blocks (fig. 2). In each cutting treatment plot, which was 2½ acres in size (330 x 330 feet), the smallest trees were cut to attain the desired basal area in the residual stand. Because of the uniformity of the stand, two randomized blocks seemed sufficient to represent the site. The size of the experimental area also limited the number of randomized blocks that could be used.

To promote acceptance of results among private landowners and sportsmen, treatments in block 1 were established adjacent to a gamelands road so they would be easily accessible as a demonstration area. This, of course, means, in a strict statistical sense, that the blocks represent *fixed effects* rather than *random effects,* which are desired; and that treatment results apply only within their respective blocks *(Snedecor 1959).*

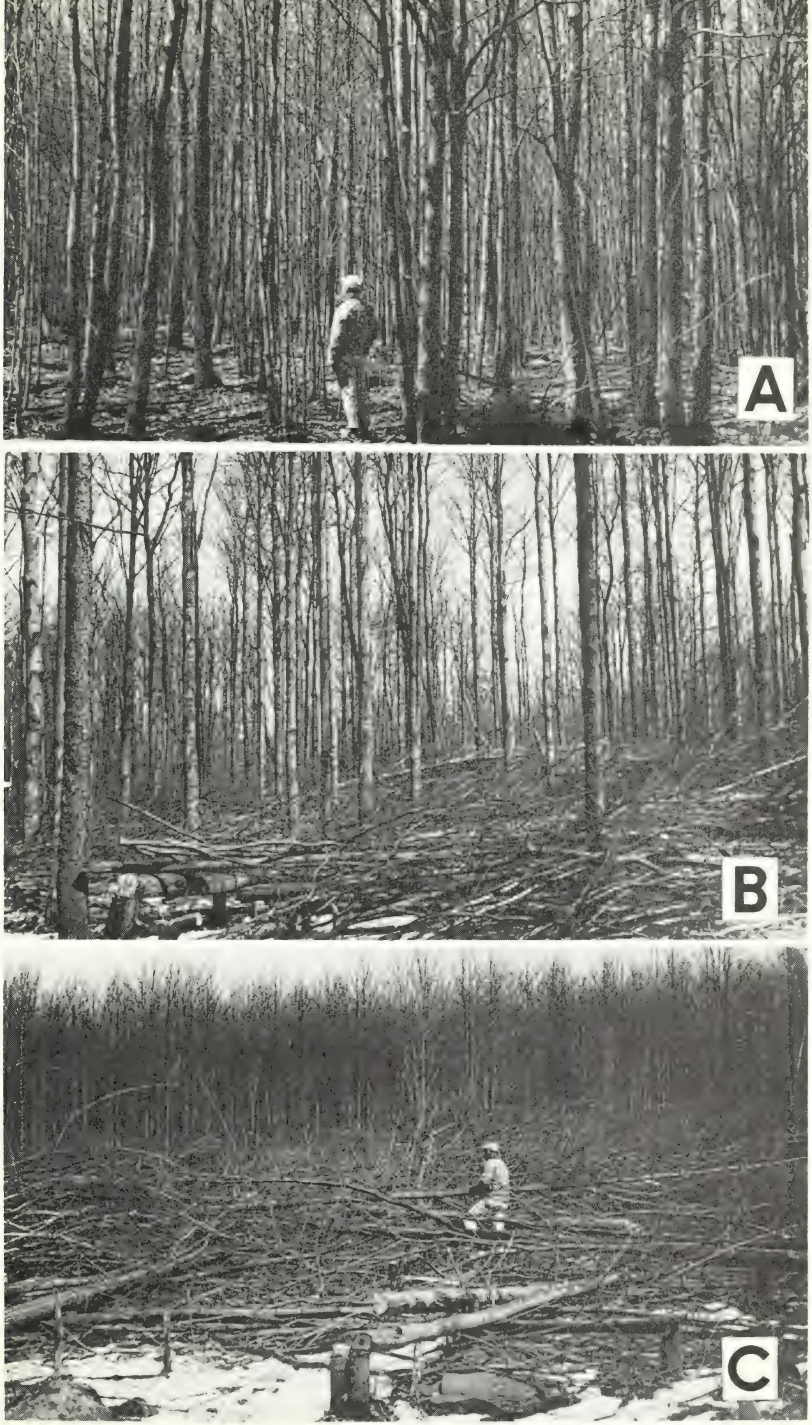
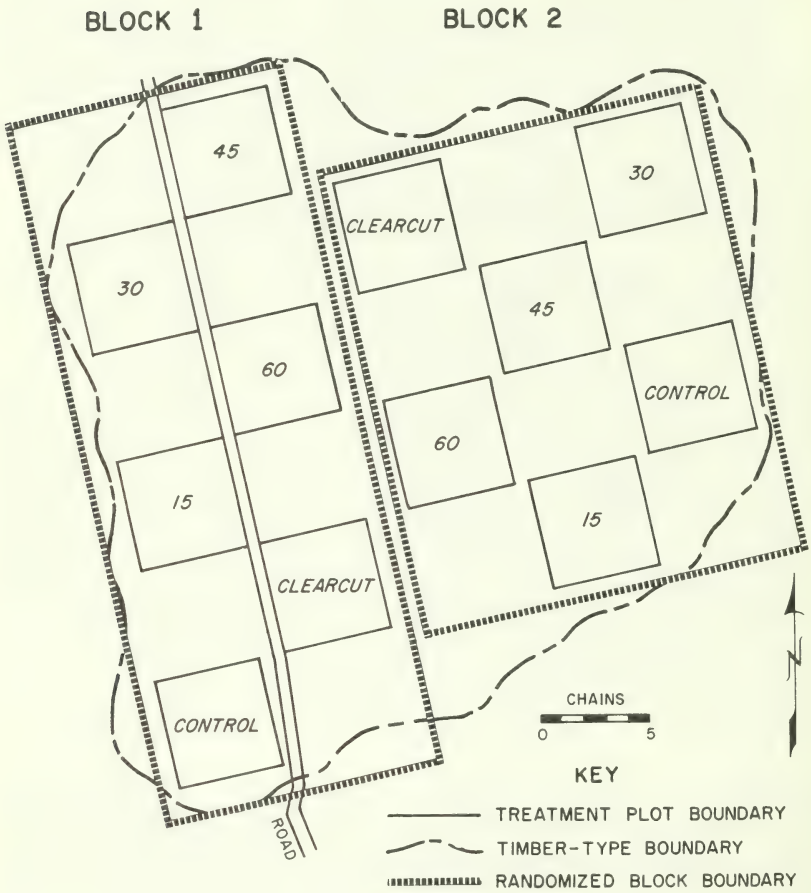


Figure 1.—Several of the treatments used in the multiple-use cutting experiment: *A*, control—no cutting. *B*, 45 square feet reserved per acre. *C*, clearcutting.

Figure 2.—Experimental design for the multiple-use cutting experiment. The basal area reserved per acre is shown within each 2½-acre treatment plot.



Furthermore, with a stand this small there was a problem of inserting two blocks within the stand. As a result, blocks are of unequal shape and theoretically cannot be considered statistically pure for representing random effects. For example, the control and 45-square-feet plots in block 1 are farther apart than any two plots in block 2.

Square 2½-acre buffer strips of undisturbed vegetation were included between treatment plots to help equalize the effects of deer mobility, and of shade and seed dispersal from surrounding vegetation.

The most desired species reserved in each treatment were dominant and codominant sugar maple *(Acer saccharum* Marsh.), black cherry *(Prunus serotina* Ehrh.), and white ash *(Fraxinus americana* L.). Red maple *(Acer rubrum* L.) was favored over beech *(Fagus grandifolia* Ehrh.). Quaking aspen *(Populus tremuloides* Michx.) and gray birch *(Betula populifolia* Marsh.) were not reserved. A record of all reserved trees was maintained by 1-inch diameter classes.

In February 1961 all trees that were to be removed were cut and left where felled. In each cutting treatment (excluding the control), all trees below 4.6 inches d.b.h. were cut; thus, the residual basal areas were all in trees of 4.6 inches d.b.h. and larger (table 1).

In hardwoods, sprouting ability (and thus browse production) of stumps declined sharply with diameter increase above 8 to 10 inches *(MacKinney and Korstian 1932).* Therefore, when browse production is the primary objective of thinning in young hardwood stands, all trees smaller than 4.6 inches d.b.h. may be cut to increase browse production.

Treatments that differed by 15 square feet per acre were assumed to provide a good indication of cutting effects through-

Table 1.—*Summary of residual basal area within each cutting treatment (excluding the control). Basal area figures are for trees 4.6 inches d.b.h. and larger; all smaller trees were cut.*

Randomized block number	Basal area per acre		
	Reserved	Cut	Total
	Sq. ft.	*Sq. ft.*	*Sq. ft.*
1	0	87.1	87.1
2	0	106.6	106.6
1	15	75.4	90.4
2	15	73.0	88.0
1	30	62.2	92.2
2	30	71.5	101.5
1	45	52.8	97.8
2	45	44.6	89.6
1	60	33.9	93.9
2	60	24.2	84.2

out a wide range in basal area. The five levels of cutting were equally spaced at 15-square-foot intervals to facilitate regression analyses of the results, as outlined by Snedecor *(1959: 346-350)*, if treatments differed significantly in an analysis of variance. There was only a sparse amount of browse per acre in the undisturbed portions of the stand, so it seemed unnecessary to measure browse in the control plots or to plan for tests of differences in browse production among the cutting treatments and a control. However, control plots were necessary in the statistical design for comparing timber growth later among the treatments and a control.

Within each treatment, the butt logs of five residual trees per species of sugar maple, red maple, white ash, and black cherry in each 1-inch diameter class (9 inches and above) were graded according to standard log-grade specifications *(Ostrander et al. 1963)*. This was done to compare crop values between treatments after several years.

Subplots

A separate random design was used to establish forty 100-square-foot circular subplots within each $2\frac{1}{2}$-acre treatment plot. Forty subplots were estimated to be necessary to obtain an average weight of dormant hardwood browse production per acre for the six major species combined that would be accurate within ± 20 percent at the 95-percent probability level *(Shafer 1963)*. Thus, α was set at 0.05 — the risk that can be taken of deciding that a difference between treatment results exists when the difference really is zero.

Measurements

First-year measurements taken during April 1962 on each subplot included:

1. Dormant browse production and utilization by use of the twig-count method *(Shafer 1963)*.
2. A count of deer pellet groups since the date of last leaf-fall (November 1961) using the method described by Eberhardt *(1960)*.
3. The presence or absence of rabbit or hare pellets.

ANALYSIS OF BROWSE DATA

Population Parameters

The statistical observation was the weight of browse production (in grams) per subplot. Browse production was expressed in four ways: gross production, net production, green weight, and dry weight. Gross production was the combined weight of browsed and unbrowsed twigs. But only the analysis of green-weight gross production is discussed in detail (unless otherwise indicated); the inferences are generally the same for the other three measurements.

Preliminary analysis of the browse measurements indicated that the treatment variances were not homogeneous, as shown by the F_{max} test *(Walker and Lev 1953: 192)* at the bottom of table 2. The ratio of the estimated standard deviation to the mean $(s/\bar{x})$ was constant enough to justify the assumption that in the population σ/u was a constant; that is, the standard deviation varied directly as the mean.

One reason why variances among treatments differed significantly is because treatment effects probably were not additive. By additive, we mean that if X_1 is the value of a given observation (browse weight) under the control conditions, then under a treatment condition

$$X_2 = X_1 + a$$

where *a* represents a constant treatment effect such as the number of deer using each treatment or the rate of browse growth under different overstory conditions. In the present experiment, treatments probably had some sort of multiplicative effect, which is expressed by:

$$X_2 = X_1 a$$

When the analysis of variance technique *(Steel and Torrie 1960)* is used to compare treatment results as in this experiment, additivity is the most important requirement and homogeneity of variance the next most important *(Snedecor 1959)*. Initial data in our experiment exhibited non-additivity and non-uniform variance, so it was necessary to transform the data.

Table 2.—*Gross browse production (green weight) before and after transformation of data for each subplot (X) to log (X + 2).*

Randomized block number	Basal area per acre reserved	Original data		Transformed data	
		Average weight of browse per subplot	$\frac{s^1}{\bar{x}}$	Average weight of browse per subplot	Standard deviation s
	Sq. ft.	*G.*		*G.*	
1	0	28.86	0.8932	1.291	0.4832
2	0	24.84	1.4496	1.076	.5803
1	15	24.21	.9586	1.226	.4450
2	15	25.06	1.0726	1.197	.4989
1	30	10.76	1.0167	.920	.4300
2	30	32.76	.8092	1.407	.3742
1	45	17.56	1.1788	1.043	.4904
2	45	17.12	1.0169	1.079	.4541
1	60	5.00	1.3860	.678	.3665
2	60	18.34	1.3418	1.005	.5439
		$F_{max.} = \frac{1296.61}{48.01} = 26.9^2$		$F_{max.} = \frac{.3368}{.1343} = 2.51^2$	
		$P\left\{ F_{max.} > 2.99 \right\} = 0.05$		$P\left\{ F_{max.} > 2.99 \right\} = 0.05$	

[1] Standard deviation per average weight of browse.

[2] $F_{max.} = s^2_{max.} / s^2_{min.}$

Transformation of Data

The logarithmic transformation described in Snedecor *(1959: 320)* was used. This transformation is necessary for unbiased tests when the standard deviation is proportional to the mean. Gross weight of browse per subplot (X) was transformed to log (X + 2); this made all subplot values positive and greater than zero. Homogeneous variance was obtained by this transformation as indicated by an F_{max} test (table 2), and additivity existed in the transformed data as evidenced by Tukey's test of additivity *(Snedecor 1959)*.

This transformation also provided homogeneous variance among treatments for *net* browse production in terms of both green and dry weight, except for the 60-square-foot treatment in block 1. There may have been either of two reasons for this discrepancy in the latter treatment:

1. The 60-square-foot treatment in block 1 resulted in the lowest browse production of all treatments (table 2): average gross production of browse was only 5 grams per subplot, and approximately half of this was utilized. Browsing on this small amount of browse during the growing season may have altered the growth pattern so that the variance observed under this treatment no longer belonged to the same population of variances as the other treatments.

2. This discrepant observation may have been an unusual member of the population being sampled.

Because no proved explanation could be found for this discrepancy, the net browse observations in the 60-square-foot treatment plot of block 1 were used in the analysis of variance, but with three precautions in mind: first, by pooling this discrepant variance estimate with the others, the standard errors of the other treatment means may have been underestimated; second, if this outlying value had been rejected, the result might have been an overestimation of errors; and third, the possibly low estimate of pooled sampling variance may have increased the likelihood of committing an alpha-type error in the analysis—that is, rejecting a true hypothesis.

Analysis of Variance

The analysis of variance (table 3), which used a fixed-effects model with sampling *(Steel and Torrie 1960: 144),* indicated that cutting treatments did not differ significantly in terms of browse production. However, the residual error mean square was significantly larger than the sampling error.

The residual error mean square was computed from observations that normally are used — if treatments are replicated within blocks — to compute a block x treatment-interaction mean square. Interaction occurs if the difference between treatment effects depends upon individual blocks. Because treatments were not replicated within blocks, it is impossible to state explicitly whether or not there was a significant block x treatment interaction. However, several factors in the design indicate that interaction probably would have been significant.

Interaction measures the failure of treatment effects to be the same for each block. Some degree of interaction is illustrated by figure 3 where the difference between blocks for the 30-square-

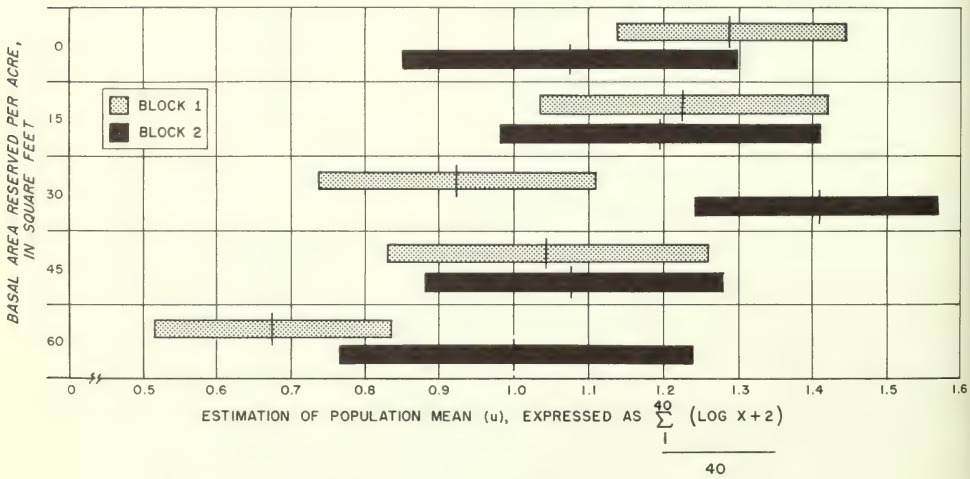


Figure 3. — Interval estimates (probability of 0.95) of browse population mean weights (green weight, gross production) — after logarithmic transformation of subplot data—for each of five cutting treatments in two randomized blocks. Mean of each sample is shown as a vertical line.

Table 3.—*Analysis of variance for gross browse production (green weight) in terms of grams per subplot after logarithmic transformation, for 5 cutting treatments on 2 randomized blocks with 40 subplots per cutting treatment plot.*

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F	F 0.05	Parameters estimated
Blocks	1	1.5588	—	—	—	—
Treatments	4	7.2175	1.8044	1.08	6.59	$\sigma_s^2 + 40\sigma_E^2 + 80K_T^2$
Residual error	4	6.6573	1.6643	6.86*	2.39	$\sigma_s^2 + 40\sigma_E^2$
Sampling error	390	94.5224	.2424	—	—	σ_s^2

$$[40(s_E^2) + s_s^2] - s_s^2 = 1.6643 - 0.2424 = 1.4219$$

$$s_E^2 = \frac{1.4219}{40} = 0.0355$$

* Indicates significance.

foot treatment, in particular, is inconsistent with the block differences for other treatments.

Factors Influencing Results

Although an equal basal area per acre was reserved in both blocks for any one treatment, the total number, basal area per acre, diameter-class distribution, and species distribution of the trees that were cut for any one treatment differed considerably between blocks. Even though the overall condition of the experimental area was fairly uniform, considerable experimental variation was introduced when the area was divided into ten 2½-acre treatment plots. Before the cutting treatments were applied, the randomized blocks differed significantly in terms of average basal area per acre for a main treatment plot. Covariance analyses, which attempted to relate browse production to initial basal areas, and basal areas cut within each treatment, did not prove successful.

If the experimental error had been estimated with 80 subplots rather than the original 40, its mean square would have been:

$$0.2424 + 80\ (0.0355) = 3.0824$$

instead of 1.6643. Thus, the variance of a treatment mean ($s_{\bar{x}}^2$) would have been:

$$3.0824/160 = 0.019$$

instead of the present value of

$$1.6643/80 = 0.021$$

This is a trivial decrease in variance to compensate for doubling the sampling rate. Any material decrease in the standard error of the treatment mean would have to be sought by increasing the number of randomized blocks, or by replicating treatment within blocks. This would provide a means of detecting block x treatment interaction if it existed.

In our experiment the standard error of a treatment mean ($s_{\bar{x}}$) was:

$$s_{\bar{x}} = \sqrt{\frac{0.0355}{2} + \frac{0.2424}{2(40)}}$$

$$= 0.142$$

It should be noted that the computed s_x probably is large because the value of 0.0355 may contain a block x treatment-interaction effect. A treatment mean, expressed as

$$\frac{\sum_{1}^{80} \text{Log } (X + 2)}{80}$$

was correct to within $(\pm 1.99)\ (0.142) = \pm 0.284$ with 95 percent confidence.

RECOMMENDED CHANGES IN DESIGN

Preliminary Decisions

First, it is necessary to consider the nature of the test of significance for any future experiment. Generally, one tests a null hypothesis (H_o) against an alternative hypothesis (H_1). Usually, the null hypothesis (H_o) is formulated as

$$H_o: m_i = m_j,$$

where m_i and m_j represent the mean weights of browse production for any two treatments *i* and *j*. As a result the alternative hypothesis (H_1) usually is

$$H_1: m_i \neq m_j$$

Second, the question arises, how large a difference *d* needs to exist between m_i and m_j before one decides from a managerial standpoint that they are significantly different? Because the many other food sources besides woody browse were not considered in the study and because deer management is based on approximate numbers of deer, we suggest that in any future study m_i should differ from m_j by at least ± 20 percent of m_i before a difference *d* is labelled significant. However, for certain experimental purposes *d* conceivably could be as small as ± 10 percent of m_i, and still be important enough to detect.

The average *transformed* weight of browse per subplot throughout all treatments in this study was 1.09 grams (table 2). Thus, in future experiments, our best estimate of a 10-percent

difference between any two treatment means is 0.109 grams; and for a 20-percent difference it is 0.218 grams ($0.10 \times 1.09 = 0.109$; and $0.20 \times 1.09 = 0.218$). It should be stressed that these quantities apply to transformed data.

A third item we need to consider in future studies is the power of the test of significance, as defined by Walker and Lev *(1953: 162)*:

$$\text{Power} = 1 - \text{Probability of a type II error}$$

where a type II error (or B error) is the probability of *not* rejecting the null-hypothesis when it is false. Thus, the power of a test of significance is the probability of rejecting the null hypothesis when it should be rejected.

One way to increase the power of a test is to increase $\propto$, which was 0.05 in the present study. The $\propto$ term is the risk one takes of deciding that $m_i \neq m_j$, when the difference is really zero. An $\propto$ of 0.05 seems reasonable for most timber-browse production experiments, and therefore, we suggest $\propto = 0.05$ for future studies.

Another way to increase the power of the test is to decrease the B term. Remember that B is the risk one takes of deciding that $m_i = m_j$, when the difference between m_i and m_j really is as large as a predetermined value *d*. We suggest that B be somewhere between 0.10 and 0.40 depending upon the importance to be attached to the results.

Required Sample Size per Treatment

Having decided upon the preliminary specifications for future browse-timber production experiments, we calculated the number of subplots (N_2) required within any treatment plot for such experiments (table 4). Subplots required were computed by using the sample-size formula for a two-tailed test in Walker and Lev *(1953: 165)* and inserting in the formula:

1. An estimate of the population variance $\sigma^2 = 0.2424$ (from table 3).
2. The appropriate value for an $\propto = 0.05$.

Table 4.—Number of randomized blocks (N_1) and subplots (N_2) per main cutting treatment plot needed to reject $H_0: m_i = m_j$ when some alternative is true.[1] The $\propto$ error is 0.05.[2]

B error[3]	The difference (d) between m_i and m_j that needs to be detected if it exists			
	± 10 percent of m_i[4]		± 20 percent of m_i[4]	
	N_2	N_1	N_2	N_1
0.10	212	12	54	3
.20	162	12	41	3
.30	124	13	32	4
.40	99	13	25	4

[1] m_i and m_j are the mean weights of the logarithmic transforms of browse per subplot for treatment i and j respectively.

[2] The risk one takes of deciding that $m_i \neq m_j$, when the difference is really zero.

[3] The risk one wants to take of deciding that $m_i = m_j$ when the difference between m_i and m_j really is as large as a predetermined difference (d).

[4] The best estimate we have of m_i is 1.09 which is the grand mean; thus 10 percent of 1.09 = 0.109, and 20 percent of 1.09 = 0.28.

3. Combinations for the prescribed values of B and *d*: that is, for B = 0.10, 0.20, 0.30, or 0.40; and *d* = 0.109 or 0.218.

Required Number of Randomized Blocks

If a new experiment consists of N_1 blocks and N_2 subplots per treatment, the predicted variance of a treatment mean ($s_{\bar{x}}^2$) would be (table 3):

$$s_{\bar{x}}^2 = \frac{0.0355}{N_1} + \frac{0.2424}{N_1 N_2} \qquad (1)$$

However, for any prescribed *d* and an $\propto = 0.05$, the value of $s_{\bar{x}}^2$ can be computed and inserted in equation 1. For the present data, when N_2 is calculated for d = 0.109, $s_{\bar{x}}$ is 0.054; and when N_2 is calculated for d = 0.218, $s_{\bar{x}}$ is 0.109. An $s_{\bar{x}}$ of ±0.054 provides confidence limits of ± 10 percent, whereas an $s_{\bar{x}}$ of 0.109 provides confidence limits of ± 20 percent at the 0.95 probability level. For example, (± 1.99) (0.109) = ±0.217; and 0.217/1.09 = ± 20 percent.

Furthermore, with regard to equation 1, acceptable values of N_2 have already been calculated in a previous section of this

paper (table 4). Therefore, the only unknown value in equation 1 is the number of blocks (N_1), which can be computed as:

$$N_1 = \frac{(N_2 \cdot 0.0355) + 0.2424}{N_2 (s_{\bar{x}}^2)} \qquad (2)$$

Values of N_1 were computed for future experiments that use the previously calculated number of subplots (N_2) for various combinations of B and *d* (table 4).

In our study, the average establishment cost per 2½-acre treatment plot was $230 when tree-cutting costs were included, and $70 when they were omitted. Installation and annual measurements per subplot were calculated to be $5 for a 5-year experiment. Thus, from these figures, costs can be estimated for any combination of blocks and subplots (table 4). For example, if 212 subplots per treatment plot and 12 blocks (table 4) are too expensive, one may revise his choice of B or *d*.

We recommend 54 subplots per treatment plot and 3 blocks, when blocks seem necessary, for most future studies. This arrangement of subplots and blocks permits detection of a 20-percent difference between any two treatment means, and provides a test of significance with a power of 0.90 (table 4).

Randomized Blocks Verses a Completely Randomized Design

In our experiment, a completely randomized design would have been just as efficient as the randomized-blocks design *(Snedecor 1956: 302)*. Therefore, in future experiments, if stands are as uniform as the one used in this study, we recommend using a completely randomized design. However, the number of treatment replications in a completely randomized layout should be equal to the number of blocks required for selected *d* and B terms in a comparable randomized-block design (table 4).

Treatment Description

On the basis of initial results from our experiment, we suggest that future studies of browse production under various cutting practices should incorporate wide differences between cutting treatments in order to detect significant differences of practical

value. Three cutting intensities recommended for similar experiments in this kind of stand are: 0 (clearcut), 45, and 90 square feet of basal area reserved per acre. However, one undesirable feature might be in not learning about the true shape of the curve of response for intermediate basal-area treatments. When timber production is the primary research interest and wildlife habitat is the secondary consideration, an experiment of this type might profitably include more than three residual densities and possibly some different variables as well.

Perhaps variation in browse data could be reduced by assigning treatments in terms of a fixed basal area to be cut within certain diameter classes and restricting cutting to two or three species such as beech, red maple, and sugar maple. However, this procedure probably would increase the variation in timber-growth data.

Large cuttings (more than 2½ acres) spaced farther apart might give different browse production-utilization results. Future experiments of this kind should have larger treatment plots—perhaps 20 to 50 acres—to help eliminate the possible effects of deer use in one treatment on deer use in another. It may be difficult to find large areas with uniform site and stand conditions and similar local deer populations, but multiple co-variance analysis techniques may help to solve this problem.

Replication of Treatments within Blocks

If randomized blocks are used, treatments should be replicated at least once within each block so that the effect of block x treatment interaction can be measured (table 5). This design also will provide a more appropriate error term for testing treatment effects. If interaction mean square is significant (table 5), then it is necessary to analyze treatment effects within each block as a separate experiment and to treat each block as a completely randomized design *(Steel and Torrie 1960: 99-100)*.

Table 5.—*Analysis of variance model for a randomized block experiment with treatments replicated within each block and subsampling of treatment plots. Components of variance for fixed effects.*

Degrees of freedom	Source of variation	Parameters estimated[1]
Blocks	(b-1)	$\sigma_s^2 + sr\sigma_E^2 + tsr\ K_B^2$
Treatments	(t-1)	$\sigma_s^2 + sr\sigma_E^2 + bsr\ K_T^2$
Blocks x treatment	(b-1) (t-1)	$\sigma_s^2 + sr\sigma_E^2 + sr\ K_{BT}^2$
Experimental error	bt (r-1)	$\sigma_s^2 + sr\sigma_E^2$
Sampling error	btr (s-1)	σ_s^2

[1] b = number of blocks, t = number of treatment, r = number of replications, and s = number of subplots.

Effect of a Location Factor

The objective of future multiple-use experiments for a given timber type may be to compare the effects of various cutting intensities at different locations so that inferences can be made from experimental results that will apply to a timber type throughout a region rather than to a specific location within that region. Usually treatments would be considered as fixed effects. Locations and blocks would be considered as random effects if specific locations and the blocks within each location were selected at random from a population of locations and blocks. The analysis-of-variance model for these conditions is outlined in table 6. An example of the calculations involved, without subsampling, is given by Snedecor *(1959: 374-375)*.

Table 6.—*Analysis of variance model for a series of randomized blocks experiments over several locations. Treatments replicated within each block and subsampling of treatment plots. Components of variance for mixed model; treatments fixed, locations and blocks random.*

Source of variation	Degrees of freedom	Parameters[1] estimated
Treatments	(t-1)	$\sigma_s^2 + bsr\sigma_{TL}^2 + bcsrK_T^2$
Locations	(c-1)	$\sigma_s^2 + tsr\sigma_{B(L)}^2 + tbsr_L^2$
Treatments x Locations	(t-1) (c-1)	$\sigma_s^2 + bsr\sigma_{TL}^2$
Blocks in location, B(L)	c(b-1)	$\sigma_s^2 + tsr\sigma_{B(L)}^2$
Pooled error	c(t-1) (b-1)	σ_s^2

[1] b = number of blocks in each location, t = number of treatments, c = number of locations, r = number of replications, and s = number of subplots.

ANALYSIS OF DEER USE

Pellet Group Counts on Subplots

The average number of deer-pellet groups per subplot are summarized by treatments in table 7. These average values serve as an estimate of deer population levels within each treatment during the winter months (November to April). Eberhardt *(1960)* pointed out that: "In open areas, or under coniferous cover, it becomes necessary to estimate the age of pellet groups." This was not done in our study, so deer use may have been overestimated in the clearcut, 15-, and 30-square-foot treatments. The forested area surrounding these treatment plots may have

Table 7.—*Average number of deer-pellet groups before and after transformation of each subplot count (X) to $\sqrt{X}$.*

Randomized block number	Reserved basal area per acre	Original data		Transformed data	
		Average number of pellet groups per subplot	$\frac{s^1}{\bar{x}}$	Average number of pellet groups per subplot	Standard deviation s
	Sq. ft.	*No.*		*No.*	
1	0	2.12	1.09	1.12	0.95
2	0	1.70	1.32	.90	.96
1	15	1.57	1.49	.80	.98[2]
2	15	1.35	1.20	.87	.78
1	30	1.00	1.58	.65	.76
2	30	2.22	.92	1.20	.85
1	45	.85	1.38	.60	.71
2	45	.80	.139	.58	.68[3]
1	60	.17	.265	.16	.39[4]
2	60	1.00	1.20	.69	.71

$F_{max.} = \frac{5.43}{0.20} = 27.15$[5] $F_{max.} = \frac{0.96}{0.47} = 2.04$[5]

$P\left\{F_{max.} > 2.99\right\} = 0.05$ $P\left\{F_{max.} > 2.99\right\} = 0.05$

[1] Standard deviation per average number of pellet groups.

[2] Maximum standard deviation.

[3] Minimum standard deviation.

[4] Omitted data.

[5] $F_{max.} = s^2_{max.} / s^2_{min.}$

contributed a certain amount of leaf cover but probably not enough to eliminate completely this source of error. However, the analysis of this data is presented here to show the procedures and models that were used.

Homogeneous treatment variances—except for the 60-square-foot treatment in block 1—were obtained by transforming the count of pellet groups per subplot (X) to $\sqrt{X}$. The hypothesis of additivity for the transformed data was accepted by means of Tukey's test of additivity.

Relation Between Cutting Intensity and Deer Use

Basal area cut per acre (X) was related to the average of the square-root-transformed number of deer-pellet groups per subplot (Y) within that treatment. The regression

$$Y = 0.168 + 0.009X$$

which was significant at the 0.01 level, accounted for about 58 percent of the total variation in the dependent variable (fig. 4).

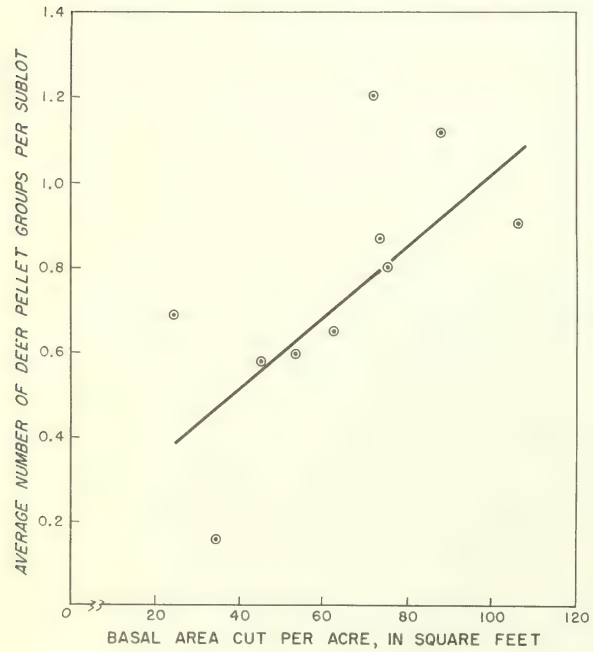


Figure 4. — Regression of deer use during the winter period (expressed as the average number of deer pellet groups per subplot, after the square-root transformation of subplot data) and basal area cut per acre.

This is a model I (fixed X) after Snedecor *(1959: 126)*. Regression model IA *(Snedecor 1959: 153)* was not appropriate, even though the standard deviation was proportional to the mean in the original data, because the logic of the situation did not permit the assumption that the regression passes through zero. The slope of the line probably would have been less if the age of the pellet groups had been estimated in the heavier cuttings.

ANALYSIS OF RABBIT USE

The percentage of subplots within each treatment and block that contained rabbit pellets (not aged) is shown in table 8. Analysis of variance of the arcsin transformed values (table 9) indicated that the 45- and 60-square-foot treatments differed significantly. Furthermore, the clearcutting of 2 ½-acre areas did not result in a greater rabbit frequency—during the first year after cutting—than the average of the 15-, 30-, 45-, and 60-square-foot basal-area reserve cuttings. The same inference can be made concerning the 15-square-foot basal-area reserve treatment vs. the average of the 30-, 45-, and 60-square-foot treatments, and the 30-square-foot reserve treatment vs. the average of the 45 and 60. One possible explanation may be that increased overstory density offers protection from winged predators and offsets the protective advantages of slash density in heavily cut areas—up to a 45-square-foot reserve cut. However, these results may also be related to other variables not measured in this study.

Table 8.—*Percentage of 40 subplots per treatment and block containing rabbit pellets.*

Randomized block	Basal area per acre reserved, square feet				
	0 (clearcut)	15	30	45	60
1	17	12	27	30	2
2	20	5	20	20	5

Table 9.—*Analysis of variance for arscin transformed values of percentage of subplots with rabbit pellets.*

Source of variation[1]	Degrees of freedom	Sum of squares	Mean square	F	F 0.05
Block	1	13.96	—	—	—
Treatment:	4	565.56	141.39	9.35*	6.39
1 vs. 2, 3, 4, 5	1	25.36	25.36	1.68	7.71
2 vs. 3, 4, 5	1	63.77	63.77	4.22	—
3 vs. 4, 5	1	101.62	101.62	6.72	—
4 vs. 5	1	374.81	374.81	24.80*	—
Error	4	60.45	15.11	—	—

[1] The treatment numbers from 1 through 5 denote, respectively, the reserve basal area treatments of 0 (clearcut), 15, 30, 45, and 60 square feet per acre.

* Indicates significance.

ANALYSIS OF SPROUT GROWTH

Although sprout growth usually is considered less desirable than seedling reproduction from the timber manager's point of view, sprout growth is analyzed here because:

- It is important for wildlife food and cover.
- The procedures used to compare sprout growth under the various cutting treatments are applicable to seedling reproduction measurements.
- The data may prove useful to timber managers for prediction purposes or in deciding how to avoid excessive sprout growth.

A stocked subplot was considered as one that contained at least one unbrowsed terminal leader of hardwood sprout growth. Treatment results are summarized in table 10. Two analyses of variance were made (table 11) using the arcsin transformed values of the percentages of subplots stocked with: sprout growth of red maple, sugar maple, black cherry, or white ash; or sprout growth of any of the above species or beech, in the 1.0- to 4.9-foot height class.

The results indicated that, when species other than beech were considered, the clearcutting treatment resulted in a significantly greater percentage of stocked subplots the first year after

Table 10.—*Percentage of subplots in each treatment and block stocked with spout growth of (1) red maple, sugar maple, black cherry, or white ash, and (2) any of the above or beech in the 1.0- to 4.9-foot height class.*

Type of sprout growth	Randomized block	Basal area per acre reserved, square feet				
		0	15	30	45	60
Red maple, sugar maple, black cherry or white ash	1	30	30	10	12	7
	2	20	12	10	10	5
any of the above species or beech	1	37	35	42	30	10
	2	35	20	32	17	20

Table 11.—*Analysis of variance for arcsin transformed values of percentages of subplots stocked with (1) red maple, sugar maple, black cherry, or white ash, and (2) any of the above species or beech, in the 1.0- to 4.9-foot height class.*

Source of variation[1]	Degrees of freedom	Sum of squares	Mean square	F	F 0.05
RED MAPLE, SUGAR MAPLE, BLACK CHERRY, OR WHITE ASH					
Blocks	1	56.83	—	—	—
Treatments:	4	331.64	82.91	14.04*	6.39
1 vs. 2, 3, 4, 5	1	167.07	167.07	10.70*	7.71
2 vs. 3, 4, 5	1	133.43	133.43	8.53*	—
3 vs. 4, 5	1	3.84	3.84	.24	—
4 vs. 5	1	27.30	27.30	1.75	—
Error	4	62.40	15.60	—	—
ANY OF THE ABOVE SPECIES OR BEECH					
Blocks	1	30.96	—	—	—
Treatments	4	304.64	76.16	1.03	6.39
Error	4	294.27	73.57	—	—

* Indicates significance.

[1]The treatment numbers from 1 through 5 denote, respectively, the reserve basal area treatments of 0 (clearcut), 15, 30, 45, and 60 square feet per acre.

cutting than the average of the other cutting treatments. And the 15-square-foot reserve cutting resulted in a greater percentage of stocked subplots than the average of the 30-, 45-, and 60-square-foot treatments.

When all unbrowsed sprout growth, including beech, was considered, none of the treatments differed significantly in terms of stocking. Beech browse was low-preference deer food within the study area, which may account for an abundance of unbrowsed beech for all treatments.

LIMITATIONS OF THE DATA

If the procedures or the results outlined in this paper are used in the design or analysis of future timber-wildlife experiments, at least three limitations of the data need to be considered:

1. By using the variance of one year's browse-measurement data across five cutting intensities, statistical inferences have been made concerning the appropriate design for future studies of browse-timber production. These inferences assume that timber-growth data, which is not yet available for this study, will contain about the same, or less, variation than the browse-measurement data.
2. The stand in which the experiment was conducted was fairly homogeneous with respect to age, basal area per acre, species composition, aspect, and soil type. Experiments on less uniform areas would very likely produce greater variances than were reported for this study.
3. The confidence limits and designs recommended in this paper provide the basis for a series of yearly analyses over the lifetime of the experiment. Any analysis based upon sums or means over several years should provide relatively more accurate estimates than those obtained for any one year.

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